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CLAY AND SHALE RESOURCES
IN
PENNSYLVANIA

By
HENRY LEIGHTON

DEPARTMENT OF INTERNAL AFFAIRS
WILLIAM S. LIVENGOD, JR., *Secretary*
TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, *State Geologist*

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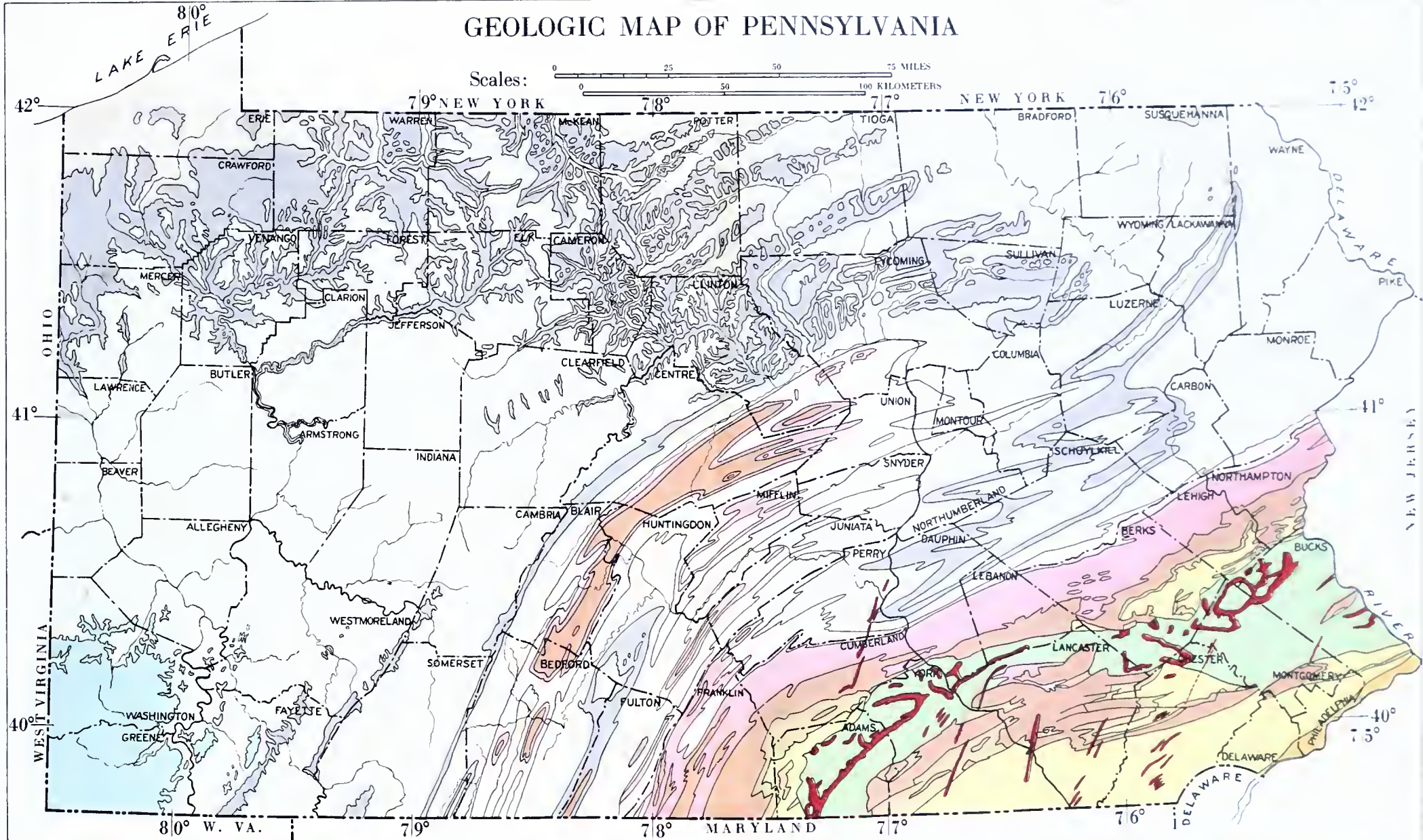
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GEOLOGIC MAP OF PENNSYLVANIA



KEY (See Stratigraphic Chart.)



CLAY AND SHALE RESOURCES OF PENNSYLVANIA

By HENRY LEIGHTON

INTRODUCTION

A study of the clay resources of Pennsylvania was initiated by the State Geological Survey in 1925. Mr. George Longeor of Marcus Hook, Pa., collected many samples in that year, especially from Centre, Clearfield, Clinton, Fayette, Somerset, and Westmoreland Counties. These samples were given physical tests in the ceramic laboratory at State College under the direction of Prof. J. B. Shaw, and chemical analyses were made under the supervision of Prof. T. W. Mason. The results of this study were published as Bulletin M 10 of the State Geological Survey in 1928 under the title, "Fire Clays of Pennsylvania" (partial report), by J. B. Shaw.

Since 1929, the author of this bulletin has continued the clay investigations. The most active field work was from 1929 to 1934. The clays and shales of the greater part of the State have been studied, including those in use and those readily accessible for possible use. The physical tests of samples collected by the author were made by Prof. J. B. Shaw and Mr. G. J. Bair of State College and the chemical analyses by students under Prof. T. W. Mason.

The results of a part of this investigation were published as Bulletin M 17 of the State Geological Survey in 1932. This bulletin dealt with the clays and shales of the southwestern counties, Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Indiana, Lawrence, Washington, and Westmoreland.

A special study of the white clays of the State was made by the writer and published as progress report 112 of the Geological Survey in 1934.

The report that follows brings together the available information about the clays and shales in the counties not covered by Bulletin M 17.

Clay and shale and the products made from them constitute one of the most important mineral resources of the State.

Every county in the State has workable clays or shales within its boundaries, and there are few counties that have not at some time produced some ceramic products. Glacial clays are abundant in the northeastern and northwestern counties; bedded shales are found in nearly every county; fire clays of high quality accompany the bituminous coals in the western counties; alluvial clays are present on the flood plains and terraces along the main rivers, and residual white or colored clays are to be found in many areas in the central and eastern parts of the State.

MINERALOGY OF CLAYS AND SHALES

Clay is a substance difficult to define. It might be described as a natural earth made up of finely divided mineral particles, chiefly hydrous aluminum silicates, and, in general, having plastic properties when wet and drying to a firm body. No definite chemical or mineral composition can be given for it and its chief qualities are fineness of grain and plasticity. The only exception to this definition would be that of flint clay which is non-plastic.

Clays have been studied and classified by various methods, of which the most important are chemical analysis, dehydration curves, petrographic microscope, ultra-microscope, and X-rays. The study of the diffraction patterns produced from clays under X-rays is a rather recent and a very promising mode of attack and is yielding good results in the definition and study of the purer clays.

Clay is a rock made up of minute scales and shreds of mineral matter known as the clay minerals, with smaller amounts of extraneous impurities such as quartz grains, small scales of mica, pyrite crystals, carbonaceous matter, limonite, and other minerals. The clay minerals are frequently aggregated into masses dispersed with difficulty but when they are separated they can be seen as clear scales ranging in size from two to twelve microns (.002 to .012 mm.). Still smaller particles are revealed with the ultra-microscope, these forming the colloidal portion of the clay.

Recent study of the clay minerals places them in three or four groups as shown in the following table:

Clay Minerals

Mineral	Chemical formula	Crystal form	Index of refraction	Birefringence	Per cent SiO ₂	Per cent Al ₂ O ₃	Per cent H ₂ O
Kaolinite	Al ₂ O ₃ .2SiO ₂ .2H ₂ O	Monoclinic plates and worm-like bundles	1.557-1.566	.002	46.5	39.5	14
Beidellite	Al ₂ O ₃ .3SiO ₂ .nH ₂ O	Orthorhombic scales and shreds	1.49-1.536 Iron-rich 1.55-1.60	.032-.051	51	28.7	20.3
Halloysite	Al ₂ O ₃ .2SiO ₂ .nH ₂ O	Isotropic-amorphous	1.47-1.542	none	43.5	36.9	19.6
Montmorillonite	Al ₂ O ₃ .5SiO ₂ (MgCa)O.nH ₂ O	Rhombic plates	1.51	.023	50.6	17.23	23.32*

* CaO-3.21; MgO-4.56.

The purer unconsolidated clays, such as kaolin, contain identifiable kaolinite scales and bundles of scales. The less pure surface clays seem to be made up largely of iron-rich beidellite scales with occasionally small amounts of kaolinite. Shales are largely made up of beidellite scales oriented in parallel position. This orientation, together with variations in grain size and in impurities, produces the laminated structure of the shales. Plastic fire clays apparently are mixtures of halloysite and unoriented scales of beidellite and kaolinite, compacted into an aggregate very difficult to break up.

Flint clay seems to be halloysite or some similar amorphous compound which, to a varying degree, has been recrystallized into kaolinite, often showing the worm-like bundles, and, in lesser degree, to beidellite.

Among the extraneous impurities there should be noted the almost constant presence of minute rods and grains of a yellowish, highly refracting mineral which probably is rutile. These grains have a size of about one micron (.001 mm.). They are found uniformly scattered throughout the amorphous base of the flint clays and in lesser amounts in the kaolin portion and in the plastic clays. Small scales of muscovite are common in clays, and still smaller scales of sericitic mica are present and may alter to a substance known as hydromica. Although some authors think that hydromica is a transitional mineral between mica and kaolinite, others question the identity of the mineral and believe it to be beidellite.

The coloring matter in clay is largely made up of tiny specks of opaque or dark brown organic matter and dots of limonite.

The coarser impurities, such as quartz, pyrite, feldspar, zircon, and others, can generally be washed from the clay and studied separately. Unless in large amounts they have little effect upon the properties of the clay and therefore require little attention.

The quality of a clay seems to depend upon the clay minerals themselves and these demand much more study than they have received. The work of Ross and Shannon and others has brought out the fact that these clay minerals may, in themselves, furnish the content of iron, calcium or magnesium which has often been attributed to extraneous impurities.

Among the more important papers upon the mineralogy of clays are the following:

- Galpin, S. L., Studies of flint clays and their associates, Trans. Amer. Cer. Soc. XIV, p. 307, 1912.
- Larsen, E. S., and Wherry, E. T., Leverrierite from Colorado, Jour. Wash. Acad. Sci., VII, p. 208, 1917.
- Ries, H., Clays, their occurrence, properties and uses, New York, 1927. Pp., 53-95 contain an excellent summary of the work done on the mineralogy of clays and an excellent bibliography is included.
- Ross, C. S. and Kerr, P. F., The kaolinite minerals, U. S. Geol. Surv. Prof. Paper 165-E, p. 151, 1931.
- Ross, C. S. and Shannon, E. V., The minerals of bentonite and related clays and their physical properties, Jour. Amer. Cer. Soc. IX, p. 77, 1926.
The chemical composition and optical properties of beidellite, Jour. Wash. Acad. Sci. XV, p. 467, 1925.
- Somers, R. E., Microscopic study of clays, U. S. Geol. Surv. Bull. 708, p. 292, 1922.

PROPERTIES OF CLAY AND SHALE

Types of clay in which the minerals are so closely matted together that it is difficult or impossible to separate them are low in plasticity. Such clays, even after fine grinding or a long period of stirring in water, are still seen under the microscope to be made up of granular aggregates rather than separated scales of the clay minerals. The plastic clays, on the other hand, break down very rapidly into separated particles. Plasticity is also reduced by the presence of quartz grains or other sandy material.

The color of clay is due largely to very minute particles of yellow or red iron oxide or dark particles of carbonaceous matter scattered through the clay aggregate. Greenish colors are due to the presence of shreds and scales of chlorite and related minerals. The color is, of course, greatly modified during burning and the final colors are chiefly due to the quantity of iron oxides and to the state of their oxidation.

The question of the burning qualities of a clay involve not only the chemical composition but also physical qualities such as fineness of grain, porosity, rate and method of burning, and other factors. In general it is very difficult to predict the burning qualities from a chemical analysis. Physical tests, including actual burning tests, are of much greater importance.

The clays of Pennsylvania range from pure kaolins and pure fire clays down to very impure siliceous, ferruginous, calcareous, and carbonaceous varieties. They may be classified as follows:

Classification of Clays and Shales

Alluvial clays	high terrace, plastic flood plain, sandy or plastic.	
Glacial clays	bluish or buff, plastic.	
Residual clays	kaolins, siliceous white clays or plastic colored clays.	
Triassic shales	red or greenish soft shales.	
Paleozoic bedded deposits	Shales	{ pure clay-shale
		{ red, green, micaceous, sandy, black.
	Clay	{ fire clay. { flint clay.
		{ semi-flint clay.
		{ plastic or bond clay.
	red.	
	gray, calcareous.	

Alluvial clays. Alluvial clays are such impure clays as are deposited along the low banks of the rivers during flood, and so forming the flood plains. They are generally buff, sandy, or silty clays, but if the stream is ponded and slow-moving they may be of finer grain and highly plastic. All alluvial clays burn red. Similar plastic clays of like origin, lying upon terraces above many of the larger rivers, are known as terrace clays. Alluvial and terrace clays have been used in the manufacture of common brick and tile, stoneware, and flower pots.

Glacial clays. During the Pleistocene period, glaciers covered the northwestern and the northeastern parts of Pennsylvania, and as they retreated left large accumulations of glacial drift. Much of this was bluish clay carrying many boulders and known as boulder clay. Hills of this material make up much of the moraine deposits of the glaciers and much of it underlies some of the deeply buried valleys in the glaciated areas. Glacial clays, although plastic, are impure, red-burning clays. They were formerly much used in making brick but the presence of boulders and lenses of sand and gravel within them, and their irregular pockety occurrence, work against their use today.

Residual clays. Residual clays are those derived by the slow disintegration and decomposition of the rock which underlies them. They represent the insoluble, more stable portions of a rock which has undergone long decay. If the rock is an igneous rock, such as the dark diabase of the Triassic belt or the igneous rocks of the South Mountain area, the feldspar in the rock has altered to clay minerals. The residual clay thus formed will be a light-colored kaolin if the igneous rock was of light color and low in iron-bearing minerals, and a yellowish brown to dark red if the parent rock was rich in iron, as are diabase or basalt.

If the parent rock was a limestone, the residual clay represents the insoluble clay impurities left after the soluble lime compounds have been removed. This clay is usually red or yellow and is a common cover over much of the limestone valley areas in central and southeastern Pennsylvania.

In some places in Pennsylvania white residual clays, often siliceous, overlie cherty beds, quartzites, or quartz schists. These represent insoluble clay portions of these rocks or the decomposition of feldspathic grains in the original sandstones. The principal white clays of the State are of this type. They are used as firebrick cement, as paper clays, in white tile manufacture, as a whitener for portland cement, and other purposes. Some are derived from pre-Cambrian schists, some from Cambrian quartzites, and some from Oriskany cherts.

Residual clays are also derived from the decay of schists in southeastern Pennsylvania and this material is used in brick-making.

Interbedded clays. Numerous beds of non-laminated, structureless clay are interbedded with the other strata of the Permian and Carboniferous periods. The purer types are generally below coal beds or beneath a carbonaceous streak which represents the horizon of a coal bed. These are termed underclays. The less pure types are interbedded with the sandstones, shales, and limestones and may underlie any of them. Why some of the clays deposited during the Carboniferous period have become shales while others have remained as clays is a problem. Also the question is still unsolved as to why some of the underclays are pure fire clay and others are ordinary impure clay.

The origin of fire clay has been discussed at length by many authors¹ but no agreement has been reached. There seems to be a close relation between the formation of the coal beds and that of the clay, and the clay seems to have been purified by some leaching process in the coal swamps. The writer believes that consideration should be given to the similarity in structure between fire clays, red clays, and calcareous buff clays. All are without lamination, that is, they are structureless, and, unlike the clays deposited in earlier strata of the Paleozoic, they have not been transformed into shale. It would seem that the swamp waters of the Carboniferous brought about a colloidal precipitation of all three types of clay different from the ordinary sedimentation which produces shale.

Fire clays are practically pure hydrous aluminum silicates with little of the fluxing elements such as iron, calcium, magnesium, sodium, or potassium which lower the fusion point. Fire clays are refractory, that is, they fuse only at very high temperature. This property, coupled with proper shrinkage and porosity at certain burning temperatures, determines the quality of the fire clay. It may be classed as the best or No. 1, or may be rated as No. 2 or 3. The lower grades are made into fire brick not requiring high heat or can be used in making face brick or sewer pipe. The fire clays of this region are mostly underclays but the thickness of the overlying coal bears no relation to the thickness or quality of the clay. The normal plastic fire clay is light bluish gray, has a smooth soapy feeling, and may have smooth polished surfaces known as slickensides. These are due to movements in the clay mass. A frequent impurity is iron carbonate or iron sulphide in lumps or nodules scattered through the clay. These

¹Hodson, F., The origin of bedded Pennsylvanian fire clays in the United States: Jour. Am. Ceramic Soc. v. 10, pp. 721-746, 1927.

Stout, W., Origin of coal formation clays: Ohio Geol. Surv. 4th Ser. Bull. 26, pp. 533-568, 1923.

Lovejoy, E., Notes on fire clays of the northern Appalachian coal basin: Jour. Am. Ceramic Soc. v. 2, pp. 374-390, 1919.

are very detrimental to the clay and must be removed if possible. Fire clay may grade downward into a very sandy clay, almost a sandstone at the base. The outcrop of a fire clay often is a bleached white clay which may give one a false idea of its quality.

Flint clay is a hard non-plastic fire clay which breaks with a smooth conchoidal fracture like flint or fine-grained limestone. It occurs as an underclay, either as a definite bed or as part of a bed of plastic fire clay. Often it is a lenticular mass in the plastic clay. It may be too siliceous or too ferruginous to be of value but usually it is a purer and more refractory clay than the plastic variety. Like the other fire clays it may carry detrimental nodules of the iron compounds but one has to be careful in condemning it because some nodules in flint clay are a highly aluminous compound, in part diaspore, which gives the clay a high refractory nature. It is difficult to judge the quality of a flint clay by visual examination. Flint clay is non-plastic and when used must be mixed with a plastic clay as a bond.

Semi-flint is an indefinite term given to some of the harder plastic fire clays which lie between flint and plastic clay in their appearance and qualities.

It should be said as a word of caution that all underclays are not fire clays although fire clay is the common miners' term for underclay. Many underclays are suitable only for manufacturing face brick.

Gray clays interbedded with the sandstones and limestones of the Carboniferous, especially in the Conemaugh group, are light colored and resemble fire clays in their crumbly structureless nature. These are usually very disappointing when tested because commonly they are high in lime and tend to fuse at a low temperature and very suddenly. Such clays are of no value. Some clays of this type, however, are of somewhat better grade and could be made into face brick and other products. Again the visual examination fails and their quality is determined only by a series of tests. Microscopic examination discloses no extraneous impurities. It is probable that their impurities, such as lime, have been adsorbed into the clay substance and are therefore not removable.

Red clays form brilliant bands in the Mauch Chunk series, and the so-called "Red beds" in the Conemaugh group. Some of the material is red shale but most of it true clay. It is crumbly and structureless, mottled occasionally by patches of green clay or shale. It also may carry nodules of lime carbonate. This clay is quite plastic and is excellent material for the manufacture of red face brick and tile.

Shale. The shales represent aggregates of clay minerals which, during deposition or through subsequent pressure, have taken on a lamination which permits them to be split into thin layers. Some shales are broken down with difficulty so that they are only moderately

plastic after fine grinding or long weathering. Many are weakly plastic and require the addition of surface soil or plastic clay to make them workable.

Pure clay-shales are generally of a light buff color. They have a slightly soapy feeling and when placed between the teeth give no feeling of grit. Such shales are of high grade and may be used in making face brick, paving brick, and sewer pipe as well as common brick and tile. They generally burn to a red color, very few shales being so free from iron that they will burn to lighter colors.

Red shale makes up a large part of the Triassic strata, and is also the larger part of the Catskill beds at the top of the Devonian, and appears frequently at other positions in the Paleozoic. If not too sandy, it generally makes good brick and tile.

Green shales owe their color to ferrous iron silicates such as chloritic matter and may be as rich in iron as the red shales. They burn red and are used in making brick and tile.

Micaceous shale is crumbly and non-plastic on account of the scaly mica it carries. It is usually of no value.

Sandy shale has a gritty feel and does not break into such thin laminations as a pure shale. There are all gradations between a thinly bedded shaly sandstone and a sandy shale. A small amount of finely divided sand is beneficial in a brick mixture as it reduces the shrinkage and gives a more open porous body. A shale that is too sandy has a low plasticity and cannot be molded well or handled easily in the green state. Many of our shales are of low plasticity and must be mixed with weathered shale from near the surface or with more plastic surface clay. Care in quarrying and mixing the various types is essential to good brick making.

Black shale is high in carbonaceous matter and is seldom used in brick making. It is low in plasticity and its carbon content can only be removed by extremely slow burning. The carbon tends to give the brick a dark porous core and causes harmful swelling.

PHYSICAL TESTS

The laboratory tests of clays to determine their physical characteristics have been made in many government bureaus and private testing laboratories, and under the influence of the American Ceramic Society have become standardized. Tests on the clays of Pennsylvania were conducted in the laboratories of the ceramic department of Pennsylvania State College under the direction of Prof. J. B. Shaw. His methods were discussed in Bulletin M 10 of the Pennsylvania Geological Survey but it seems wise to describe them again in this report.

The clay is first ground and passed through a 20-mesh sieve. Water is then added to it until it is of the proper consistency for molding.

A personal factor enters at this point but experience shows that workers judge the point of best plasticity very uniformly. From the feel the operator classifies the clay as of good, fair, or poor plasticity. The clay is then molded into bricks 1 by 1 by 2 inches in size and these are carefully weighed. Their volume is then determined in kerosene in a volumeter. They are then dried to constant weight at 110° C. and weighed. The water lost is termed the water of plasticity and is calculated in percentage of the dry weight. It is the amount of water needed to bring the clay into a plastic state. Some authors prefer to call it the tempering water. It varies from about 15 percent up to 33 percent in Pennsylvania clays. Water has no direct relation to the plasticity, or to the shrinkage of a clay but does in a measure reflect these properties. High water of plasticity usually indicates that a clay will have a high air shrinkage and a long slaking period. Twenty-three samples of Pennsylvania flint clays averaged 19.7 percent water of plasticity, 6.6 percent volume drying shrinkage, and 2.9 minutes of slaking. Twenty-two samples of No. 1 or No. 2 plastic fire clays in the State averaged 21.3 percent water of plasticity, 13.5 percent volume drying shrinkage, and 9.8 minutes of slaking. Five samples of the Carmichaels clay, a surface clay, averaged 32 percent water of plasticity, 23.8 percent volume drying shrinkage, and 12 minutes of slaking. These represent respectively clays of low, medium, and high plasticity and their relation in the three tests is striking. Other clays and shales are variable in quality but their water of plasticity will average around 22 percent.

Shrinkage water. The amount of water that would be necessary to fill every pore of the dried briquette is called shrinkage water. It represents the porosity of the briquette, and it is calculated by the use of the following two formulæ:

$$\text{Dry volume in cc.} = \frac{\text{Dry weight in grams}}{\text{Specific gravity}}$$

$$\text{Percent shrinkage water} = \frac{\text{Wet volume in cc.} - \text{Dry volume in cc.} \times 100}{\text{Dry weight in grams}}$$

Pore water. The difference between the percentage of water of plasticity and the shrinkage water is called pore water.

Drying shrinkage. The amount of shrinkage in a clay during drying may be measured and expressed in two ways, as linear shrinkage, and as volume shrinkage. Either may be determined and the other calculated or both may be determined as a check. Linear shrinkage is determined by molding a bar of clay 1 by 1 by 6 inches in size and making on the wet bar two marks 10 centimeters apart. The

bar is then dried and the distance between the marks measured; the linear shrinkage is computed in percent of the dry length. Volume shrinkage is determined by finding the wet volume of a molded block of clay, drying it, and then determining its volume when dry. These tests are made with the use of a volumeter. The shrinkage is stated in percent of the dry volume. Formulae and tables have been devised for changing linear into volume shrinkage and vice versa but in this report both are given. Linear shrinkage is easier to determine but is apt to be less accurate.

Drying shrinkage varies from 2 up to 35 percent in volume, the plastic clays usually showing a higher shrinkage than the lean ones. The addition of sand or grog to the clay will reduce its shrinkage. Sandy shales and clays therefore have low shrinkage. Flint clays have a low volume shrinkage ranging from 1.5 to 13.9 percent in the clays investigated. Plastic fire clays of No. 1 and No. 2 quality ranged from 1.4 to 23.1 percent and averaged 13.5. Surface clays like the Carmichaels clay on the high river terraces ranged from 17.1 to 35 percent in volume shrinkage and averaged 23.8.

Slaking. Some confusion exists in the use of the word slaking. Originally it was used to indicate the disintegration of clay when wholly or partly submerged in water. The test was applied to lumps of raw clay or shale. Some clays break down very quickly and others are not affected even after being submerged many days. This test gave the clay worker an idea of the ease by which the clay could be disintegrated at the plant or during a curing process.

Now, however, time of slaking refers to the number of minutes necessary to bring about the disintegration of a molded piece of clay immersed in water. There is no relation between the two types of slaking and this second test is applied as an indication of the plasticity of the clay, as it seems to be a simple and fairly good indication of that property. The test was made at the State College laboratory by molding two 1-inch cubes of clay, drying them at 110°C., placing them on a 4-mesh screen immersed in water to such a depth that the top of the cube was just out of water. The bottom of the cube was 1 inch above the bottom of the pan. The time necessary for the disintegration of the material so that it would fall through the screen was recorded in minutes as the time of slaking. Flint clays averaged 2.9 minutes, plastic fire clays 9.8 minutes, and very plastic surface clays 12 minutes.

Modulus of rupture. The test for modulus of rupture determines the strength of the clay to resist rupture by direct pull. It has also been termed the tensile strength. It determines the green strength and in that way gives an idea as to the handling qualities of the brick

while in the unburned state. The test is made by molding briquettes of clay in cement-testing molds, drying them at 110° C. and then pulling them apart in a standard cement-testing machine. The result is stated in pounds per square inch. Interpretive tests were made of the neat clay, of equal parts clay and sand, and of the clay burned at 1150° C. Plastic clays with a high drying shrinkage usually show a high green strength, while sandy clays, flint clays, and many kaolins have a very low modulus of rupture. Most of the clays tested showed a green strength between 100 and 300 pounds per square inch. Twenty-six percent had a strength of less than 100 pounds; this included most of the flint clays and residual kaolins, and also some of the poorer shales and a few plastic fire clays. Four percent of the clays examined had a modulus of rupture of over 400 pounds. These included shales, plastic underclays, and surface clays.

BURNING TESTS

Tests to determine its burning or firing qualities are made on clay by burning air-dried pieces at various temperatures in a kiln. The clays of this investigation were burned to the following temperatures in degrees Centigrade: 1000, 1050, 1100, 1150, 1200, 1250, 1300, 1350. The temperature of the kiln, either in the laboratory or in actual practice, is usually determined by a thermo-electric pyrometer which indicates the temperature on the dial of a galvanometer or records it on a revolving drum, or else by the use of pyrometric cones, known also as Seger cones. These cones are small pyramids so made of blended and graded clays and fluxes that they will fuse at certain definite temperatures. The number on a cone indicates that the cone will bend over when the temperature corresponding to that number is reached. The cones of interest in connection with the tests in this report are shown in the following table,¹ in which the cone number and its corresponding temperature value are given.

Melting point of Orton standard pyrometric cones

No.	°C.	°F.	No.	°C.	°F.	No.	°C.	°F.
010	950	1742	5	1230	2246	19*	1510	2750
09	970	1778	6	1250	2282	20	1530	2786
08	990	1814	7	1270	2318	23	1590	2894
07	1010	1850	8	1290	2354	26*	1600	2912
06	1030	1886	9	1310	2390	27*	1620	2948
05	1050	1922	10	1330	2426	28*	1635	2975
04	1070	1958	11	1350	2462	29*	1650	3002
03	1090	1994	12	1370	2498	30*	1670	3038
02	1110	2030	13	1390	2534	31*	1685	3065
01	1130	2066	14	1410	2570	32*	1705	3101
1	1150	2102	15	1430	2606	33*	1720	3128
2	1170	2138	16	1450	2642	34*	1740	3164
3	1190	2174	17	1470	2678			
4	1210	2210	18	1490	2714			

¹ Coal formation clays, Geol. Survey of Ohio, 4th Ser., Bull. 26, p. 482, 1923.

* Corrected temperature from C. W. Kanolt, U. S. Bureau of Standards.

Like clays, the cones do not have a definite melting point and indicate only approximate temperature. However they do measure faithfully the effects of the heat upon the ware because they are undergoing the same changes as are the products being burned. By reference to the table above it will be seen that the temperatures used in our tests correspond to cones 07½, 05, 02½, 1, 3½, 6, 8½, and 11. The burned pieces at each temperature are studied as to color, hardness, and tendencies to warp or crack. Determinations are then made of the shrinkage, porosity, and specific gravity of the test pieces.

Shrinkage. Shrinkage usually begins about cone 010 or 950° C. and increases as the temperature of the kiln is raised until a maximum is reached beyond which the brick begins to swell and deform. This point where swelling begins is termed the overburning point and is the danger line in clay burning. Clays very high in silica may swell before this point is reached, but ordinarily swelling and an increase in porosity indicate that the clay has reached its maximum burning temperature. The manner in which the clay shrinks during the burning is a very important indication of its value. It may shrink rapidly at first and then maintain a low but uniform shrinkage over a long range of temperatures; it may shrink at a uniform rate to a certain cone and then very suddenly swell or fuse; it may not shrink much until a very high temperature is reached. Such variations are best expressed by shrinkage curves.

Two definitions in regard to range of burning are given by Stull.² Heat range he defines as "the range of temperature over which the ware burned shows comparatively no difference in quality or appearance for one kind of product (as for example, paving brick)". That is, shrinkage and porosity would remain fairly constant over the heat range and their curves would flatten out. Burning range, also termed firing range, he defines as "that range of temperature over which the clay gives one or more different desirable products, as for example, very porous common brick, moderately porous face brick, and vitrified paving brick." In other words, the burning range represents the temperatures at which some kind of usable product may be made from the clay.

Shrinkage may be determined as linear or volume shrinkage expressed in percent of the original size. Clays vary greatly in their shrinkage. Sandy clays and flint clays generally show a low shrinkage and more plastic clays a higher one. The range lies between practically no shrinkage up to 13 percent linear or 34 percent volume shrinkage. The following table gives some averages obtained in this investigation.

² Stull, R. T., Coal formation clays: Geol. Survey of Ohio, 4th Ser., Bull 26, p. 480, 1923.

Average burning shrinkage and fusion point of Pennsylvania clays

	Percent linear burning shrinkage	Cone of maxi- mum shrinkage	Cone of fusion
17 flint clays -----	4.9	3 (1190°C.)	31 (1685°C.)
19 plastic fire clays -----	5.7	4 (1210°C.)	29 (1650°C.)
52 shales used in brick making -----	6.7	2 (1170°C.)	11 (1350°C.)
73 shales, unused -----	7.1	01 (1130°C.)	12 (1370°C.)
63 plastic clays, underclays but not fire clays -----	5.7	2 (1170°C.)	19 (1530°C.)
9 surface clays -----	8.6	1½ (1160°C.)	14 (1410°C.)

Porosity. The amount of pore space in a brick is termed its porosity. This decreases as the shrinkage increases, but there is no exact relation between porosity and shrinkage and both are usually determined. They supplement each other. A brick is usually most porous at the end of the oxidation period in its burning, that is, after the water and other gases have been driven off and before any particles of the mass begin to fuse together. This point of greatest pore space is about cone 010 for most clays. As the temperature is increased from this point the pore space diminishes until complete vitrification is attained and the porosity drops almost to zero. The brick may continue at this stage over a long range of temperature, after which it swells and becomes porous again. This takes place at the point of overburning. The curve of porosity, like the curve of shrinkage, is very useful to the ceramist in judging the value of a clay. The porosity is determined by saturating the burned test piece in water, determining the weight of water absorbed, which in turn is converted into volume, 1 cc. of water weighing 1 gram. This is only the apparent porosity or the volume absorption, for saturation is never quite complete. For these tests the brick were boiled two hours in distilled water and then soaked in water for 24 hours. It should be noted that porosity is the volume of the spaces in the brick as compared to the volume of the entire brick; absorption is the weight of the absorbed water as compared to the weight of the dry brick.

In burning from cone 010 to cone 14, porosities decrease on the average about as follows: flint clays from 37 to 31, plastic clays from 30 to 8, shales from 28 to 8.

Absorption. Absorption is related to porosity as above stated and is determined from the same calculations. It should be termed apparent absorption because, as with porosity, the pores do not become completely saturated with water.

Specific gravity. Determinations of the specific gravity of a clay at different stages in its burning are of interest to the clay worker and a number of them have been made for this report. The specific gravity may be calculated and stated in three ways. First, as true

specific gravity, which is the gravity of the particles exclusive of the pores; second, as apparent specific gravity, which is the specific gravity of the test piece including the pore space not saturated with water during soaking; and third, as bulk specific gravity, the gravity of the test piece taken as a whole mass with pore spaces included. True specific gravity will, of course, be the greatest figure, apparent the next, and bulk specific gravity the lowest. One example would be a burned clay whose gravities were as follows: true 2.66, apparent 2.45, and bulk 2.29.

Fusion point. Clay is a mixture of various minerals, each with its own point of fusion, and therefore can have no definite point of melting or fusion. Parts of the mass begin to fuse at a comparatively low temperature and we say that the brick is in the stage of incipient vitrification. As the heat is increased the constituents continue to fuse together until the whole mass is vitrified. This stage is maintained for a longer or shorter period or heat range, after which the brick becomes so soft that it loses shape or swells. This point of deformation is the point the writer selects as the fusion point although some authors prefer to term it the softening point or the deformation point. With a cone, it is the point when the tip bends over and touches the base.

The fusion point is best determined by molding clay into small cones and actually fusing them in some type of high heat furnace, using Orton cones as a check on the temperature. Prof. Shaw used a specially designed oxy-acetylene furnace for these determinations. Attempts have been made to calculate the fusion point of a clay from its chemical analysis but, on the whole, it is better to use the analysis only as a rough indication of fusibility, and use an actual fusion for the more accurate determination.

The clays examined in the State range in fusion point from cone 5 (1230°C) up to cone 34 (1740°C .) As seen in the preceding table the average cones of fusion of the various types of clay are as follows: flint clay 31, plastic fire clay 29, plastic underclays other than fire clays 19, shales 12, and surface clays 14.

CHEMICAL ANALYSIS

The methods used in the quantitative analysis of clay have been thoroughly described in texts on analytical chemistry and are also given by Ries.³ The analysis usually includes the determination of the following substances: SiO_2 , Al_2O_3 , Fe_2O_3 , TiO_2 , CaO , MgO , K_2O , Na_2O and Ign. or loss on ignition. In addition, in some analyses the amount of FeO is separated from Fe_2O_3 , and determinations are

³ Ries, H., *Clays: Their occurrence, properties and uses*, p. 105, 1927.

made of the amounts of MnO , P_2O_5 , and SO_3 . The loss on ignition is made up chiefly of combined water but of course includes such volatile constituents as CO_2 , SO_3 , and gases given off by organic matter.

The analyses of the clays discussed in this report were made by students in the chemical laboratories of Pennsylvania State College, under the direction of Prof. T. W. Mason. They were made in duplicate and carefully checked but may contain minor inaccuracies.

A pure clay should consist of one or more of the clay minerals without any extraneous matter or absorbed salts. If the clay mineral is one of the kaolinite group with a formula $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ the clay should contain 46 percent SiO_2 , 39.5 percent Al_2O_3 , and 14 percent H_2O . Many china clays and fire clays approach this formula in purity. If, on the other hand, the clay mineral is beidellite, $(\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot n\text{H}_2\text{O})$, montmorillonite, or some other complex clay mineral, it might show quite different amounts of water, silica, or alumina and in addition might contain appreciable amounts of iron, calcium, or magnesia.

Impure clays are those which, in addition to the clay mineral, contain grains or crystals of foreign matter such as quartz sand, pyrite crystals, small rods of rutile, nodules of limonite, particles of carbonaceous material, tiny rhombohedrons of calcite or siderite, and many other minerals. These appear in the analysis as impurities or excessive amounts of their respective elements.

Less information can be gleaned from the chemical analysis of a clay than from a series of physical tests, and in most instances a chemical analysis is unnecessary, especially of lower grade clays.

The following points may roughly be deduced by a study of a clay analysis:

1. An approach to the formula of kaolinite indicates a refractory clay.
2. High content of CaO , MgO , Na_2O , K_2O , or Fe_2O_3 indicates low fusibility.
3. Low iron content indicates that the clay will burn to a light color.
4. High iron content, unaccompanied by high lime, will burn red.
5. Al_2O_3 content over 40 percent indicates high refractoriness.
6. SiO_2 over 60 percent indicates a sandy clay.

Many attempts have been made to devise a formula whereby the refractoriness of a clay may be calculated from its chemical composition and some success has been achieved with the higher-grade clays. In most cases, however, it is simpler, quicker and cheaper to apply a direct fusion test.

TYPES OF CLAY AND THEIR USES

From a study of the physical and chemical tests of clays given in this report and other publications, it is possible to decide the best uses for any particular clay or shale. The interpretation of the tests usually conforms closely to the results obtained in actual plant practice. The clays described in this report come mainly under the following types.

China clays. For the manufacture of china, a white-burning kaolin is required. Such clays are nearly always siliceous and must be carefully washed to eliminate the gritty material. If the siliceous portion is of medium or coarse grain little difficulty is experienced in separating the white clay portion. In the Pennsylvania white clays, however, the silica content is very finely divided and the washing process becomes difficult and expensive. Various attempts have been made to produce china clay of sufficient purity to manufacture white ware but none have proven successful. Either the silica is too finely divided or the clay does not burn to a white product. Further development of washing devices may succeed in producing a pure clay from the Pennsylvania white clays at some time in the future.

Paper clays. Clays of sufficient whiteness and free from grit are much used in filling smooth-coated paper such as is used in books and in the manufacture of cardboard and plaster board. Some of the white clays of the State are washed and sold for these purposes.

Rubber clays. Much white or buff kaolin is now used in rubber mixtures to increase wearing qualities. Most of this clay now comes from the southern Atlantic Coastal Plain States. Such kaolin need not necessarily be of extreme whiteness but must be free from grit. The exact qualifications are still undetermined and the only means of determining the value of such a clay seems to be by its direct trial in a rubber mixture.⁴ Whether any of our white clays after washing could be used as rubber clays is not known but such a study might be of value.

Other uses of the white clays. The white clays of the State are used chiefly now by the steel mills as a cement in setting fire brick and for various furnace linings. For this purpose the siliceous white clays do not need washing. Other uses are as a whitening agent in portland cement and as a filler in linoleum. Other possible uses are in various paints, cleaning agents, and soaps. It seems likely that uses for our kaolins deserve much more research, especially after better methods of washing have been developed.

⁴ Lang, W. B., Clay investigations in the Southern States: U. S. Geol. Survey Bull. 901, p. 25, 1940.

Fire clays. For the manufacture of fire brick and other types of ware generally known as refractories, an increasing number of materials is used. Pennsylvania is a leading producer of the two most important, fire clay and silica sand. The sands of the State which can be used in making silica brick have been described elsewhere.⁵

Clay suitable for the manufacture of any kind of refractory product is termed fire clay. This allows for a considerable range in quality, as refractories may be subject to low, moderate, or high heat, to considerable abrasion, to varied load, to the action of various slags or molten metals, or to the action of corrosive gases. For these various uses fire brick of varied types must be devised. This has given rise to the classification of fire clays into three grades known as Nos. 1, 2, and 3. This grading is based on their respective fusion points and their action during the gradual increase of firing temperature. The fusion point is of course a very necessary factor in the test of a fire clay but it must be supplemented by a careful study of the increasing shrinkage and specific gravity and the decreasing porosity during the burning of the clay.

No. 1 fire clays are those that fuse at cone 31 (1685°C. or 3065°F.) or above and whose porosity ranges from 27 to 31 percent at cone 010 to 15 to 22 percent at cone 11. In other words these clays have a slow, long range of decrease in porosity. Their best apparent burning range is from cone 6 to 15. Usually they are flint clays but they may be semi-flint or even plastic clays. Lack of plasticity and bonding power is corrected by adding a good plastic fire clay. Excessive shrinkage is overcome by adding a small quantity of crushed fire brick. The mixture is varied according to the conditions under which the product is to be used. Chemical analyses can be used only in a secondary way as an indication of the quality of a clay. In general a clay high in alumina and low in the main fluxing elements, Fe_2O_3 , TiO_2 , CaO , MgO , Na_2O , and K_2O is a high grade clay but so many factors enter into the fusing of a clay that interpretation by analysis is difficult. The physical tests are by far the most reliable guide to clay value. No. 1 clays are used almost exclusively for the manufacture of refractories because they are too valuable to use for other purposes and they require too high temperature to bring them to the density of other clay products.

No. 2 clays include all that fuse between cone 31, the lower limit for No. 1 clay, and cone 26 (1600°C. or 2912°F.). They also show a gradual decrease in porosity from 27 to 31 percent at cone 010 to 8 to 16 percent at cone 11. Their curve of decreasing porosity falls more quickly than that of No. 1 clay and their best apparent burning

⁵ Moore, E. S. and Taylor, T. G., The silica refractories of Pennsylvania: Pa. Geol. Surv., 4th ser., Bull. M3, 1924.

range is from cone 5 to 10½. They are chiefly plastic fire clays and are used as a bond with the flint clays in the manufacture of refractories of moderate heat requirements, or in making lower grade products such as face brick, stoneware, terra cotta, and sewer pipe.

No. 3 clays include all that fuse from cone 26, the lower limit for No. 2 clays, down to cone 19 (1510°C. or 2750°F.) and whose porosity decreases fairly slowly and regularly from 27 to 31 percent at cone 010 to 1 to 8 percent at cone 11. They are usually burned at cone 2 to 8, and at these temperatures give products with porosities from 15 down to 3 percent. They are used as bond in mixtures with the better fire clays, or are used alone for low heat duty refractories, or for the manufacture of buff face brick, sewer pipe, stoneware, hollow tile, and terra cotta.

The terms Nos. 1, 2, and 3 fire clay used in this bulletin are quoted from reports of tests made some years ago. This classification is now practically obsolete.

It may be well to emphasize the fact that no fire clay can be recognized or graded by visual examination alone. A good plastic fire clay should be free from grit and excessive iron staining, and a good flint clay should break with a smooth curving or conchoidal fracture, but not even an expert attempts to judge a clay without a series of burning tests.

Sewer-pipe clay. Sewer pipe are molded by forcing a stiff mud mixture through a die; the more complicated shapes are hand molded in plaster molds. The clay must necessarily be plastic and flow smoothly. Great care must be used in drying the ware so that it will not warp or crack, which means that the shrinkage of the clay must not be excessive. The ware is burned to the point of vitrification and it is desirable that this point be reached at not too high a temperature, usually between cones 5 and 10. The porosity may fall rapidly in burning so that it reaches 1½ percent at cone 02 in the lower grade clays but in this case the vitrification range should be long so that at cone 10 or higher there is no fusion. On the other hand, the porosity may remain high to cone 1 and then fall to the point of vitrification at about cone 7. Attention must also be given to the reaction of the clay to the salt glaze which is added during burning. Some clays react well and others give considerable trouble. Barringer⁶ states that to take a good salt glaze a clay should have an alumina-silica ratio of 1-4.6 up to 1-12.5. Fire clay and shale are used in sewer pipe manufacture. If fire clay is used it must be the lower grades, Nos. 2 or 3, which vitrify at cone 9 or 10. If a shale or surface clay is used it

⁶ Barringer, L. E. The relation between the constitution of a clay and its ability to take a good salt glaze. Trans. Am. Ceramic Soc., vol. 4, pp. 211-229.

must be above the general quality for these materials, as they generally do not vitrify at the right temperature or rate.

Paving-brick clay. Paving brick must be burned to a vitrified state with a comparatively low but long burning range. This requires clay with a moderate amount of fluxes. It must also have good plasticity and tensile strength. The finished product should not show an absorption above 2 percent and must be tough to resist abrasion and impact. A paving-brick clay may remain very porous while burning until cone 1 is reached, when incipient vitrification then begins. Complete vitrification is attained at cone 5 and continues beyond cone 11. Shales are the most common material used. Low grade fire clays may be used, and sewer-pipe clays are very similar in their properties.

Stoneware clay. Stoneware of better grades, such as chemical stoneware, is made from low grade plastic fire clays; commoner grades, such as crocks, jugs, and other household ware, can be made from very plastic surface clay. The main qualities are good plasticity, high tensile strength, and the burning to a dense body without excessive shrinkage. In some cases salt glaze is used and the body must react to this. Iron specks or other coarse particles are to be avoided. Stoneware made from fire clays is usually burned at cones 6 to 8.

Terra cotta clay. For terra cotta is used generally a low grade fire clay, which burns to a dense body at cones 6 to 8. It must have low shrinkage to avoid warping. Red-burning clays were formerly much used but on account of their iron content there was a tendency to overburn. Now the fire clays are preferred as they have a long range before overburning takes place.

Fireproofing and conduits are also made of low grade fire clays of about the same character as those used for sewer pipe and terra cotta. Their thin walls require that they have good drying qualities and will not warp.

Brick clays. Almost any type of clay or shale, after some experimentation or admixture of other ingredients, may be fashioned into building brick. For the more expensive, accurately molded and well colored face brick, the higher grades of brick clay are used. These grade up into No. 2 and 3 fire clays. Fire clays low in iron give a hard, dense body of uniform buff to gray color. These must be burned to about cone 8 and as they have a long burning range there is little danger or overburning. Buff face brick can also be made from calcareous clays but there is great danger of overburning as such clays have a very short range between incipient vitrification and viscosity. Red face brick are made from clays with a moderate iron content and a low amount of lime. They can be burned to a satisfactory body at a

much lower temperature than the fire clays. Face brick clays must be plastic and smooth working and above all must burn to a uniform and pleasing color. Most shales that are not too sandy or limy will make good face brick. Some have low plasticity and green strength but can be improved by allowing some of the surface soil in the quarry to mix with the shale. Some quarries also have thin fire clay layers which are added to the mixture.

Lower grades of clay or shale that burn to a firm body at temperatures as low as cones 010 to 02 are useful in the manufacture of common brick, back-up brick, chimney brick, and drain tile. These clays generally burn to a red color, may vary considerably in their sand content, and make a product with a wide range in porosity, strength, and color. For economy, they must burn to a useable body at a low temperature and must not fuse too suddenly. Generally they are molded in a stiff-mud machine and therefore must have a plastic character and a reasonable green strength. These qualities are often low in the shales of Pennsylvania but with the usual mode of quarrying, a mixture of various shales and surface soil furnishes a workable clay.

It is thus possible, from a study of the physical tests, to arrive at an approximate conclusion as to the use of any clay or shale. The figures for plasticity and green strength (modulus of rupture) give an idea regarding the working and handling qualities before burning; the drying shrinkage indicates the amount of danger from warping and cracking, the density of the dried product, and of course the loss in size from that of the original mold. It does not indicate the rate at which a clay can be dried. Some dry easily and others have to be dried with great care and very slowly. A study of the shrinkage, porosity, and specific gravity of the burned clay at various temperatures indicates its burning qualities and will, in great measure, determine its use.

DISTRIBUTION OF CLAYS AND SHALES

The surface rocks of the State include pre-Cambrian igneous and metamorphic rocks in the southeastern counties; a great thickness of Paleozoic sedimentary rocks over most of the State, including strata of all the periods from Cambrian to Permian; a belt of Triassic sedimentary and igneous rocks crossing the southeastern corner of the State from Bucks County to Adams County; small areas of clay and gravel of Lower Cretaceous age along the Delaware River near Philadelphia; terraces of Pleistocene clays and gravels along the main rivers; Pleistocene lake clays bordering Lake Erie; Pleistocene glacial drift clays over much of the surface in the northwestern and north-

eastern counties; and recent flood-plain clays along the wider river valleys.

Extensive folding and long erosion have given the consolidated rocks distinctive relief or topographic expression and have made it possible to divide the State into distinct physiographic provinces. These are shown in Figure 1 and the geology of the State is shown in Plate 1. The distribution and development of the clays and shales of the State is closely related to these physiographic provinces and their strata.

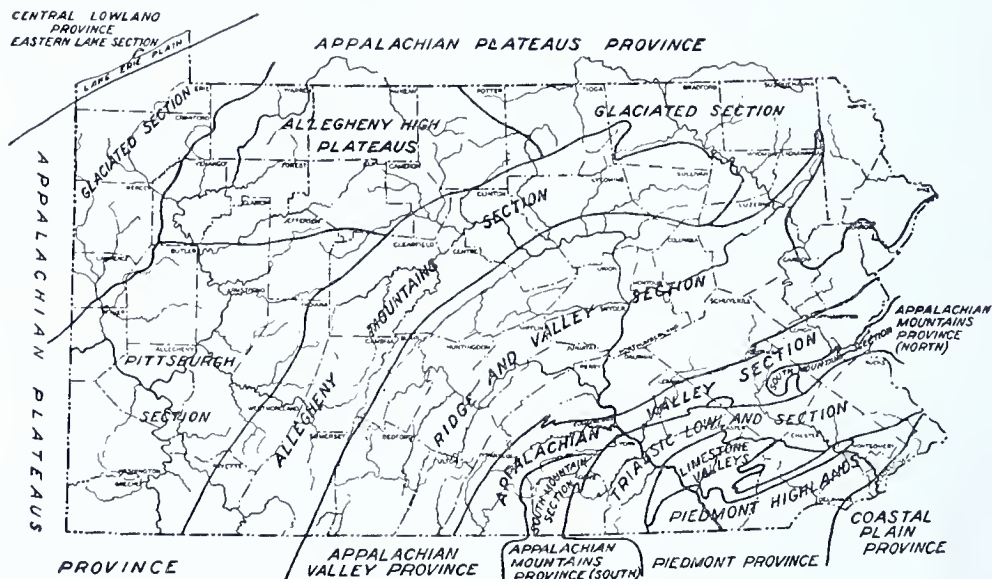


Figure 1. Physiographic divisions of Pennsylvania.

The Central Lowland province is represented in the State by the narrow belt of lake plains bordering Lake Erie in Erie County. These lake plains are the bottoms of earlier glacial lakes. The underlying bedrock is chiefly Upper Devonian shale which is used in brick making. The surface is generally covered with lake clays or glacial clays or with sands and gravels. The lake and glacial clays might be used in brick manufacture but are not so valuable as the shale.

The Appalachian Plateaus province extends south from the Erie plains and includes the western and northern portions of the State. It is bounded on the east and south by the Allegheny Mountain. The Plateaus province is an area of relatively horizontal sedimentary rocks of Devonian, Mississippian, Pennsylvanian, and Permian age forming a series of plateau levels from 1,200 to 3,000 feet above sea level. The plateaus have been deeply dissected by stream erosion so that the area is in a stage of early maturity. It is the province in which we find all our bituminous coal, petroleum and natural gas, and our fire

clays. It has, for convenience, been subdivided into sections as follows:

The northwestern glaciated section covers the northwestern counties which lie north of the terminal moraine. It is an agricultural area of subdued topography because largely covered with glacial deposits. Glacial clays are abundant but are not now used in brick making. Beneath the drift cover, the bedrock is chiefly Devonian and Mississippian shale and sandstone. Some of the shales are suitable for brick making but are little used.

The Pittsburgh section includes the southwestern counties of the State. It is an area of nearly horizontal Pennsylvanian and Permian strata rich in coal, oil, and gas, and with abundant shale much used in brick making. Plastic fire clays and flint clays are present, especially in the northern and eastern portions. The clays and shales of this section are described in Bulletin M 17.

The Allegheny high plateaus lie north of the Pittsburgh section and extend to New York State as an area of much higher plateaus, heavily wooded and chiefly underlain by Pottsville and other heavy sandstones, with smaller areas of Upper Devonian and Mississippian shales. The shales are used in a few places for brick manufacture. A few plastic fire clays have been developed in areas where clays and coals of the Allegheny group are present.

The Allegheny Mountain section is the eastern portion of the Plateaus province, from Chestnut Ridge to the escarpment forming the eastern edge of the plateau. It stands higher and is less dissected; it is, in fact, often a flat sandstone plateau. The strata are nearly horizontal and are chiefly the Allegheny and Pottsville divisions of the Pennsylvanian, the Mauch Chunk shales and Pocono sandstone of the Mississippian, and smaller exposures of Upper Devonian shales and sandstones. The Allegheny and Pottsville groups here contain many high-quality fire clays, both flint and plastic, the better flint clays generally being near the base of the Allegheny group or the top of the Pottsville series and near the escarpment. The area extends from Somerset County through Centre and Clearfield, Clinton, and Lycoming Counties.

The northeastern glaciated section, covering the northeastern counties and the Pocono plateau, is also a high plateau of horizontal sandstones and shales of the Upper Devonian, and the red Mauch Chunk shales and Pocono sandstone of the Mississippian. The surface is glaciated and many glacial clays are available. Neither the shales nor the glacial clays are much utilized and there are practically no ceramic industries.

Appalachian Valley province. East and south of the escarpment of the Plateaus province the originally horizontal sedimentary rocks of Devonian, Silurian, Ordovician, and Cambrian age have been squeezed into long parallel folds. For the most part the strata are highly tilted. The more resistant sandstones form ridges and the valleys are underlain by the less resistant shales and limestones. The Ridge and Valley section, also known as the folded Appalachian Mountains, has many good shales in the valleys and on the lower slopes of the mountains that are used for making brick and tile. Residual white clays overlie Cambrian strata and the Oriskany cherts of the Devonian. These are dug at several places and the clay is marketed chiefly as a firebrick cement. The eastern portion of the province is a wide limestone and shale or slate valley, the Appalachian Valley section, a very fertile lowland. The rocks are chiefly Cambrian and Ordovician limestones and shales. They are mantled with a red or yellow residual clay which is plastic and suitable for brick making.

Appalachian Mountain province. East of the Appalachian Valley, two prongs of the massive crystalline Appalachian Mountains enter the State. One mass, known as South Mountain, enters from Maryland and lies chiefly in Adams County. The other enters from New Jersey and as South Mountain crosses Northampton and Lehigh Counties to become the Reading Hills in Berks County. These mountains are made up of pre-Cambrian metamorphosed igneous rocks, chiefly lava flows, flanked by Lower Cambrian quartzites and quartz schists. The pre-Cambrian yields no clays but the quartz schists and quartzites in places are reduced to a siliceous white clay which is of value as a paper or linoleum clay, a whitener for portland cement, and other purposes.

Triassic Lowland section. South of South Mountain and Reading Hills is a broad lowland belt of red Triassic shales and sandstones extending from the Delaware River in Bucks County to the Maryland border in Adams County. The sediments are cut by dikes and sills of diabase which have somewhat altered the shales near the contact. The softer, more argillaceous red shales make excellent brick and several large brick yards use that material. There is no other ceramic material within the Triassic belt.

Limestone valleys. South of the Triassic belt is another belt of Cambro-Ordovician slates and limestones. The chief clay is the colored residual clay that overlies the limestone. This section includes parts of Lancaster and York Counties and the Chester Valley.

Piedmont Highlands. From Chester Valley south to Philadelphia, and from the York-Hanover Valley east to Delaware County, the sur-

face is a low rolling area underlain chiefly by pre-Cambrian schists, much weathered. Here there is little chance of ceramic materials except residual micaceous clays derived from the schists. These are little used.

Coastal Plain province. A narrow belt of sands, gravels, and clays on low terraces follows the Delaware River lowland from Philadelphia northeast to Trenton, New Jersey. These deposits range in age from Lower Cretaceous to Recent. Their clays are impure colored terrace clays suitable for brick making and for some types of pottery.

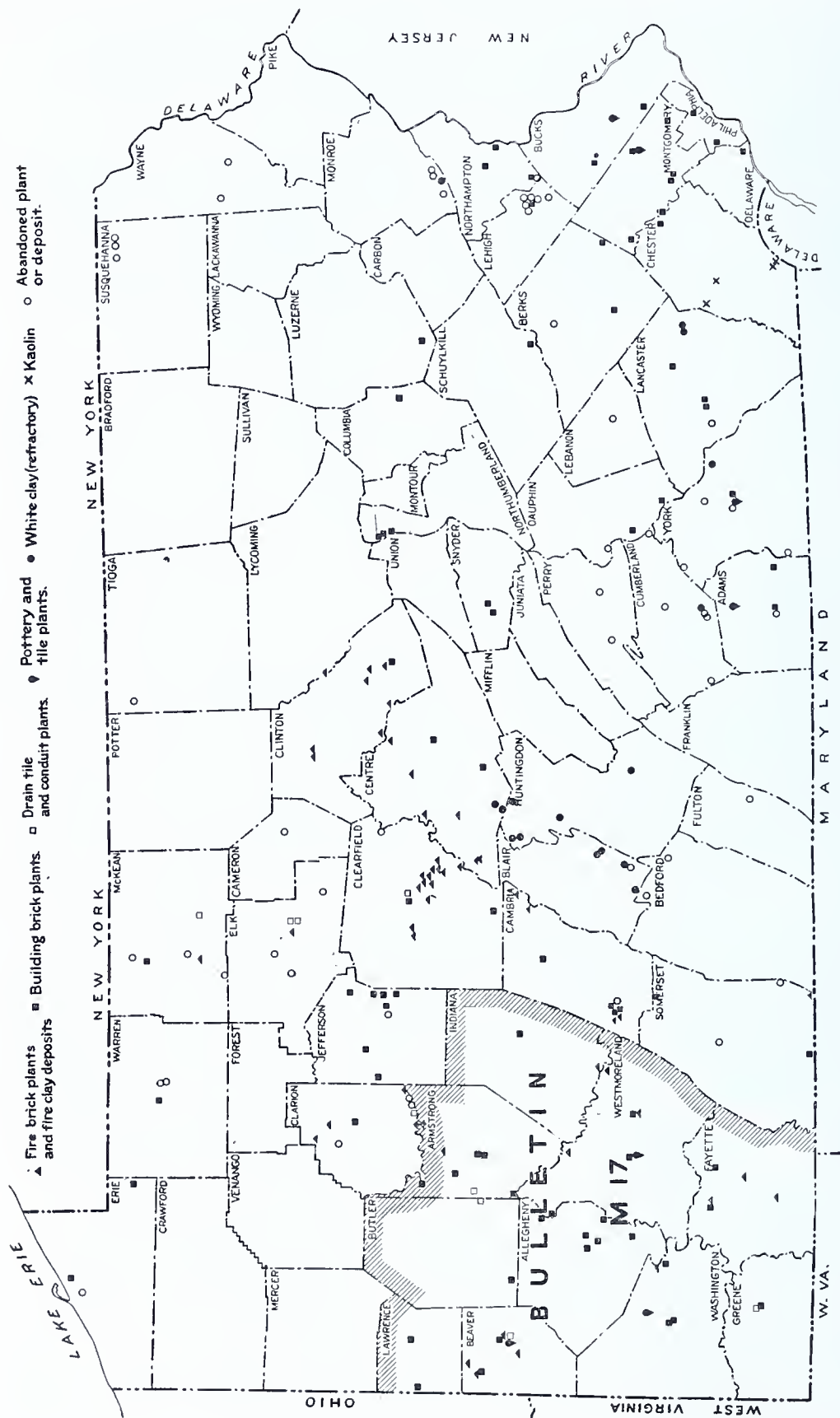


Figure 2. Map showing location of brick and tile plants.

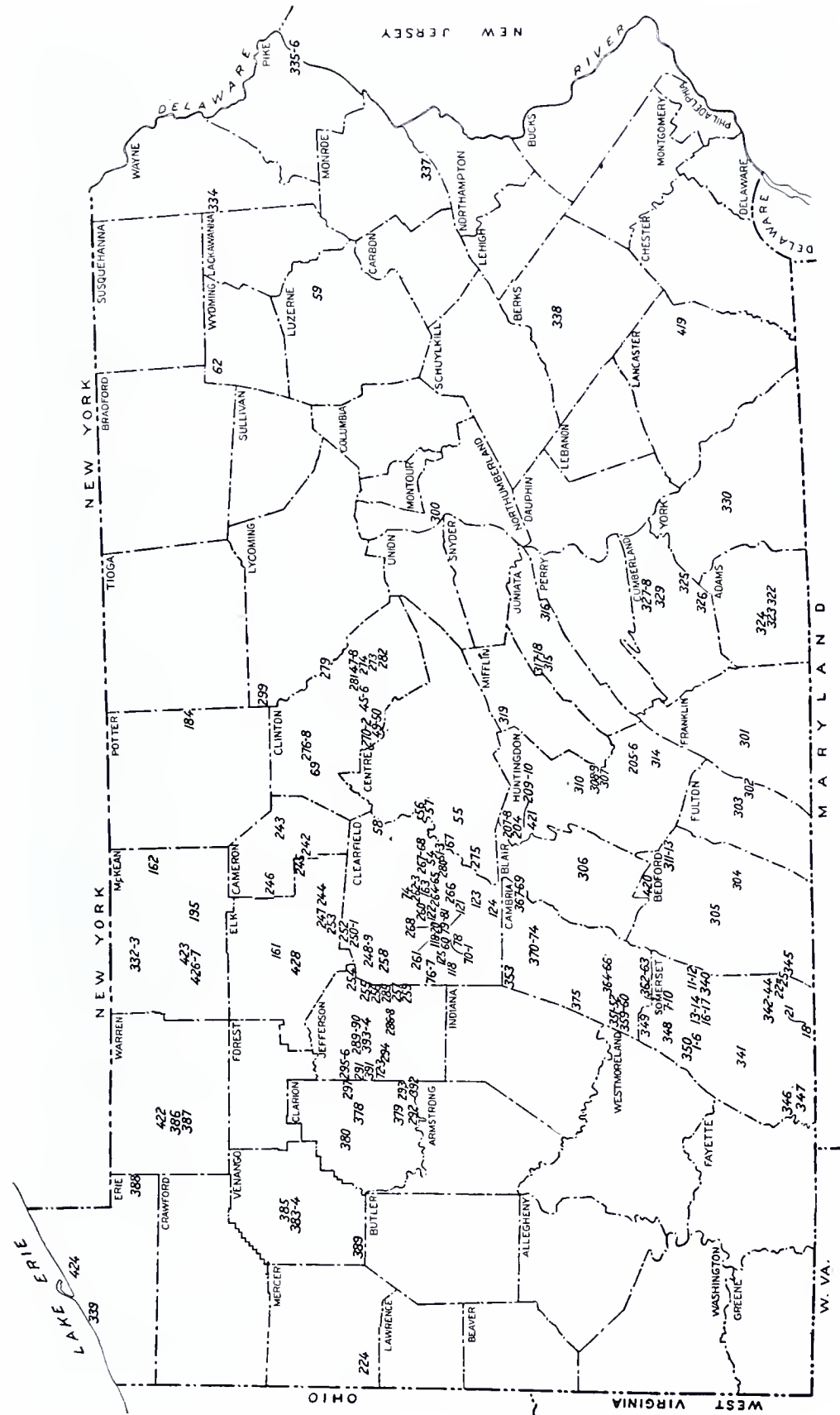


Figure 3. Map showing where samples were collected.

ADAMS COUNTY

Adams County lies along the Maryland border between Franklin and York Counties. Its western portion is South Mountain, made up mostly of pre-Cambrian rocks with smaller amounts of overlying Cambrian quartzites. The rest of the county is a low rolling plain, a part of the Piedmont Plateau. Most of this is the Gettysburg plain underlain by Triassic shales and on the southeastern border by Cambrian and Ordovician limestones. On the extreme eastern border are the Pigeon Hills, a higher mass of pre-Cambrian rocks.

The clay resources of the county are: 1. Residual, light colored clays from the Cambrian and pre-Cambrian rocks of the South Mountain area; 2. Brick shales in the extensive Triassic belt; 3. Colored residual clays in the limestone areas.

Residual white siliceous clays are formed by the decay of the quartzites and limestones of the Cambrian on the west flanks of South Mountain and in blocks of such rocks within the mountain area. Masses of such white clay were encountered in the early working of the residual limonites near Mont Alto. In Cumberland, York, and Lancaster Counties such clays are extensively developed for use in paper making, fire brick cement, linoleum filler, tile manufacture, portland cement whitener, etc. Such clay is difficult to wash completely free from very finely divided silica and up to date has not been developed as a china clay. For details concerning its use in adjoining counties see those counties. No deposits of this type of clay are known in Adams County but it seems probable that some should exist.

Within the pre-Cambrian mass there are bands of sericite-schist (a soapy, fine-grained, micaceous rock) that weathers into a siliceous light-colored clay. This has been worked near Latimore by the Central Mining Company and the Sprenkle Clay Company, but did not prove satisfactory. Proper washing of some of these sericite clays might make them available for some purposes.

At Aspers, in the northern part of the county, the Penn Tile Works Company makes white and colored floor tiles, using in part Cambrian residual white clay from adjoining counties, and in part clays from Florida. The local clays now used yield colored tile. The plant is thus a center for the development of the residual clays and turns out tile in a variety of shapes and colors. The ware is burned in down draft kilns to a temperature around cone $9\frac{1}{2}$ to 10 ($1,300^{\circ}$ C. or $2,406^{\circ}$ F.).

Triassic shales. The Triassic area, which covers the greater part of the county, consists of westward-dipping red shales and sandstones, a lesser amount of gray or greenish shales and sandstones, and

dikes and sheets of intrusive diabase, a dark igneous rock. The total thickness of these sediments in the county is 23,000 feet. Red shale predominates in such a large area and so great a thickness that it is not difficult to select material for brick making.

The lower or New Oxford division of the Triassic shale is used (1940) in brick manufacture by the Alwine Brick Company at Berlin Junction near New Oxford. The shale is crushed in dry pans, molded, dried in a waste-heat dryer, and burned in eight 30-foot down-draft kilns. The product is Colonial red face brick, both hand made and machine made. Two other firms formerly made brick in the same area, Staubs and W. H. Carbaugh.

The Drain Tile Works, located on the eastern edge of Gettysburg, has been operated by Mr. Edward J. Pfeffer for more than thirty years. The plant manufactures drain pipe from 3 to 8 inches in diameter and obtains the clay from a pit about 500 yards north of the plant. The pit is in the residual red clay of the Triassic Gettysburg shale, which is exposed nowhere in the immediate vicinity of the plant. The pit is less than 4 feet in depth at most places. It covers an area roughly 850 by 275 feet. The clay is dug as needed and hauled by truck to the plant. Rolls reduce any hard particles and the clay passes through a pug mill to the molding machine. The drain pipe is dried in the open on thin slats and finally fired in two small beehive kilns.

The Auburn Shale Brick Company operated for many years on the western edge of Gettysburg, near the College. This plant, which was abandoned about 1930, used residual clay and some of the Gettysburg shale which underlies that region. The product was rough-finished face brick molded in a Freese machine and burned in 8 beehive kilns. Much of the plant has been dismantled. The property is now owned by Mr. Gentling of Gettysburg. A sample (322) of the shale from their pit shows fair plasticity and green strength. It burned to a good brick-red color with a burning range from 1,050° to 1,150° C. It makes an excellent face brick. The firm now (1940) operates only at Auburn, Schuylkill County.

Sample 323 was taken just west of this plant in shale nearer to a diabase intrusion, which altered it to a gray color. This has a fair plasticity and green strength, burns to a brownish red with a range from 1,050° to 1,100° C. It should be classed as a poor brick shale.

A third sample (324) was taken from a road cut in the Triassic shales (Heidlersburg member). This proved to be low in plasticity. It burned to a salmon to dark brownish red with a burning range 1,050° to 1,100° C. It is not thought to be of much value as a brick shale.

In the limestone areas in the southeastern part of the county there are yellow and red highly plastic residual clays which could be used for tile, pottery, and other ware. (See No. 329, Cumberland County.)

Physical tests on clays of Adams, Franklin and York Counties

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture lbs. per sq. inch	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point at cone	Best burning range (cones)	Firing color	Suggested uses
301	20.0	3.4	4½	126	5.4	02	7	05-1	Salmon to brick red	Brick, hollow tile, drain tile
322	19.5	3.5	2	104	5.6	1	10	07-05	Brick red to red brown	Face brick
323	19.5	2.9	3	117	5.3	02	10	05-02	Brownish red	Poor grade brick clay
324	22.1	2.8	3	45	10.4	02	10	05-02	Salmon to brownish red	Little value
330	30.0	7.3	9	405	5.8	4	14	07-4	Salmon to good brick red	Floor, roofing, art tile, pottery, brick, etc.

Chemical analyses of clays of Adams and Franklin Counties

No.	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
301	5.10	59.63	7.84	.98	22.98	.81	2.39	.14	.28	.14	.31	.35
322	5.49	53.13	11.95	.67	18.14	1.25	3.34	1.74	3.74	.10	.23	.49

- 301 Martinsburg shale, 1 mile east of St. Thomas, Franklin County.
 322 Triassic (Gettysburg) shale, Gettysburg, Adams County.
 323 Triassic (Gettysburg) shale, altered by intrusive, Gettysburg, Adams County.
 324 Triassic (Heidlersburg) shale, near Gettysburg, Adams County.
 330 Plastic clay residual from Cambrian schist, West York, York County.

Selected references to the geology of Adams County:

- Frazer, P., Report of progress in the counties of York, Adams, Cumberland and Franklin: Pennsylvania Second Geol. Survey Rept. CC, 1877.
 Stose, G. W., and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (no. 225), 1929.
 Stose, G. W., Geology and Mineral Resources of Adams County, Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. C 1, 1932.

BEDFORD COUNTY

Bedford County lies between Fulton and Somerset Counties and is bounded on the south by Maryland. It is in the area of the folded Appalachians, whose high ridges and intervening valleys cross it in a northeast-southwest direction. The western boundary is chiefly the high escarpment leading up to the Allegheny Mountain section of the Appalachian Plateaus province. In succession, to the east, lie Wills-Dunning Mountain, Evitts Mountain, Tussey Mountain and along the eastern boundary Rays Hill. The mountain crests are chiefly hard, resistant quartzites and the valleys are bottomed with limestones and shales. Coal-bearing Pennsylvanian strata occur only in the northeastern corner, a portion of the Broad Top Field. The strata of the rest of the county are of Mississippian, Devonian, Silurian, Ordovician and Cambrian age. From Bedford, which lies near the center of the county, branches of the Pennsylvania Railroad extend south through Hyndman to Cumberland, Maryland, and north to Hollidaysburg. The Huntingdon & Broad Top Railroad extends northeast from Bedford to Saxton and the Broad Top districts and on to Huntingdon. The principal highways are the Lincoln (U. S. 30) and the Pennsylvania Turnpike running east and west across the county, and Route 220 extending north and south.

The clay resources of the county consist of shales suitable for brick manufacture and residual white clays. No fire clays of value are known within the area of the Coal Measures and of course would not be expected in the older strata. A brick yard near Saxton made red face brick and tile some years ago but is now (1940) out of business.

Residual white clays. Residual white clays in central Pennsylvania are associated with the Oriskany formation of the Lower Devonian or with the Gatesburg formation of the Cambrian. No white clays have been noted from the Oriskany formation in Bedford County although such clays are worked near Alexandria and Shirleysburg in Huntingdon County to the north. The two chief outcrops of Oriskany extend in north-south bands, one west of Wills-Dunning Mountain and the other east of Tussey Mountain. The Lincoln Highway crosses Oriskany outcrops near Shellsburg and near Everett.

Residual white clays associated with the Lower Ordovician and Upper Cambrian strata occur only in the area occupied by these strata along the north-central border of the county. A pit was opened by Mr. Peter Duncan, half a mile southeast of Baker Summit. In 1934 this pit was about 200 feet square and 12 feet deep. Under an overburden of 2 to 6 feet of poor clay there was exposed 7 to 10 feet

of white plastic clay and in a smaller test pit beneath is 9 feet more of clay. This clay was trucked 7 miles to Ore Hill where it was shipped to steel mills as a refractory cement. Operation ceased in 1935 when the land was included in a State Game Reserve.

J. B. Shaw gives the following tests on Sample 420 collected by the writer:

Plasticity rating 70 (medium plasticity)

Linear drying shrinkage 6.5 percent

Fired properties

Cone -----	1	5	7	9	11
Deg. C. -----	1160	1205	1250	1285	1325
Linear shrinkage—% -----	2.0	2.5	2.5	2.5	2.5
Absorption -----	24.0	23.0	21.8	21.4	21.0
Porosity -----	37.0	36.0	34.0	34.2	33.7

Fired color—white

Fusion cone 30 (1650° C. or 3102° F.)

Mr Shaw states that the clay may be used in refractories, pottery, porcelain and paint.

Shales. Shales suitable for brick-making occur in the Catskill red beds of the Upper Devonian; in the gray shale of the Middle Devonian (Portage and Hamilton) and in the Clinton formation of the Silurian.

The brilliant red shales of the Catskill formation may be seen near the western borders of the county along the Allegheny escarpment and along the eastern border of the county in a belt surrounding the Broad Top Coal Field and swinging down in the Rays Hill and Sideling Hill areas along the eastern border. Much of it is exposed through Juniata Crossing and Breezewood on the Lincoln Highway.

The Catskill shales were used by the Saxton Shale Brick and Tile Co. This company some years ago operated a plant with two dry pans and nine round kilns and manufactured red face brick and tile. The sandstone layers were discarded and the shale used. A sample (no. 313) showed good plasticity and fair green strength. It fired to a light red to red brown with a firing range from 1000° to 1150° C. Its linear drying shrinkage was 3.1 percent and its volume shrinkage 9.6 percent. It fused at cone 13 (2534° F. or 1390° C.). From the tests and from the satisfactory use made of this shale it is evident that the Catskill red shales may be used successfully in brick making.

The gray shales of the Middle Devonian are not now used in brick making in the county but are frequently exposed along the roadsides and railroads in the western and eastern sections of the county. They are frequently too sandy to be of value but with careful selection good

shales should be available. In the eastern section samples were taken as follows:

No. 304. Gray shale on Lincoln Highway just east of Everett. This has a fairly good plasticity and a low green strength. It fired salmon to dark red with a firing range of 1100° to 1200° C. From these and the tests given in the table it is evident that it would make fair grade brick, hollow tile or drain tile.

No. 311. A soft steeply dipping shale along Route 26 just south of the Huntingdon County line and near the Huntingdon & Broad Top Railroad, about 4 miles north of Saxton. Plasticity is fairly good and green strength good. It fires light red to good brick red with a firing range from 1000° C. to 1150° C. A fair clay for face brick, hollow tile and drain tile.

No. 312. A soft olive-green shale on road south of Saxton. This has fairly good plasticity and low green strength. It fires dark salmon to red brown with a firing range of 1100° to 1150° C. It could be used for face brick.

These tests indicate that the softer shales of the Devonian belt from the Huntingdon County line, through Saxton and Everett and to the south are good shales for making face and common brick and tile.

The western belt of Devonian is very similar. Sample no. 345 was taken about 3 miles south of Hyndman, along Route 96. This shale has fairly good plasticity and fair green strength. It fires red but has a short firing range. It is suggested for uses in light weight aggregates.

Devonian shales form a broad belt east and west of Shellsburg and no doubt useful brick shales could be found there. Shale possibilities in the central belt of Silurian and Ordovician strata are not promising. The chief shale lies at the Clinton horizon and one sample (no. 305) of such shale was taken along the Lincoln Highway one mile east of Wolfsburg. This is a brown shale at the Pennsylvania Railroad crossing. Plasticity was fairly good and green strength fair. It fired to a salmon to dark red brown with a firing range of 1100° to 1150° C. From these and the tests in the table it is evident that this shale would make common brick or poor-grade face brick.

It is evident that Bedford is well supplied with shales suitable for face brick, hollow tile and drain tile, especially in the eastern Devonian areas. The Clinton shale of the central area also carries some useful shale as does the western Devonian. White residual clays may be expected only in the north-central area of Cambro-Ordovician rocks and these may be of value in refractories and chinaware manufacture.

Physical tests of Bedford County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slacking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point cone	Best burning range cones	Firing color	Suggested uses
304	20.9	2.4	15	92	6.3	4	14	03-4	Salmon to dark red	Fair grade brick, hollow tile, drain tile
305	20.9	4.6	6	135	6.3	02	15	03-1	Salmon to dark red	Common brick, poor grade face brick
311	21.0	4.1	9	153	4.7	02	10	07-1	Light red to good brick red	Face brick, hollow tile, drain tile
312	18.2	3.3	15	72	4.7	1	15	03-1	Dark salmon to red brown	Face brick
313	18.1	3.1	5	135	5.8	1	13	07-1	Light brick red to red brown	Face brick, hollow tile, drain tile
345	20.0	4.1	6	234	4.1	02	10		Red	Light weight aggregates
420		6.5			2.5	5	30		White	Refractories, pottery, porcelains, paints

Chemical analyses of Bedford County clays

No.	Ign.	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
311	8.12	54.22	8.47	.48	18.47	4.59	2.19	.74	2.55	.02	.29	.00
312	4.26	62.36	13.01	.88	13.08	1.03	3.50	.26	2.83	.02	.10	.64
313	4.48	61.60	5.65	.16	22.23	.81	4.06	—	—	.23	.10	.00
345	5.68	59.72	6.67	.21	19.47	1.25	2.75	3.28	5.68	.01	.08	.44

304 Devonian gray shale, Everett.

305 Clinton shale, 1 mile east of Wolfsburg.

311 Devonian shale, 4 miles north of Saxton.

312 Devonian shale, south of Saxton.

313 Catskill shale, Saxton.

345 Devonian shale, 3 miles south of Hyndman.

420 White clay, ½ mile southeast of Baker Summit.

Selected references to the geology of Bedford County:

Butts, C., Description of the Ebensburg Quadrangle: U. S. Geol. Survey Geol. Atlas, Ebensburg folio (no. 133), 1905.

Gardner, Jas. H., The Broad Top Coal Field of Huntingdon, Bedford and Fulton Counties: Pennsylvania Topog. and Geol. Survey, Report 10, 1913.

Stevenson, J. J., The Geology of Bedford and Fulton Counties: Pennsylvania Second Geol. Survey Rept. T2, 1882.

BERKS COUNTY

Berks County lies south of Schuylkill and Lehigh Counties. It is traversed from north to south by the Schuylkill River. The county is bordered on the north by the sharp Kittatinny or Blue Mountain, the southern ridge of the folded Ridge and Valley province. South from it lies the broad expanse of the Great Valley. Beyond this are highlands of Cambrian and pre-Cambrian rocks projecting into the county from the southwest and from the northeast, generally known as the Reading Hills. South from these highlands the southern part of the county is made up of Triassic lowlands, chiefly red shales and sandstones. In the extreme southern corner Ordovician and Cambrian rocks again appear.

The northern portion of the county flanking Kittatinny Mountain is a wide belt of Ordovician (Martinsburg) shale. This belt is higher and has a more rolling topography than the limestone belt to the south. The Schuylkill River crosses the shale belt from the Kittatinny Mountain on the north to Leesport on the south. The shale is exposed between Leesport and Mohrsville. Sample 338 represents material from a roadside quarry south of Mohrsville uncovering 20 feet of weathered shale. The plasticity was fairly good and green strength fair. It fired to a salmon to good brick red with a firing range from 1100° to 1150° C. Between Shoemakerville and Mohrsville the Glen-Gery Shale Brick Corp. has used the Martinsburg shale in brick making. This plant has been closed for several years. Gray or reddish shales of the Martinsburg formation continue on through Hamburg and to the base of the mountain. With proper selection of a somewhat weathered portion it is evident that good brick can be made from the shales of the "Shale Belt." The Glen-Gery Shale Brick Corp. is now (1940) operating one brick yard in Berks County, at Wyomissing, southwest of Reading. Weathered Martinsburg shale is ground, screened, and burned in down-draft beehive kilns, using coal for fuel. The product is wire-cut and Colonial red face brick.

The belt of Ordovician and Cambrian limestones crosses the central line of the county from northeast to southwest just north of the Reading Hills and swings around the eastern upland of pre-Cambrian to its southern flank. Yellow and red plastic residual clay rests on these limestones and occasional pockets might be large enough to work. The general experience in other counties is that such clays are of excellent quality for floor and art tile, various types of pottery, and in some cases common or face brick.

The mass of pre-Cambrian with its accompanying Cambrian quartzites, quartz schists, and phyllites forms the highlands northeast of Reading and south of Wernersville. These areas should con-

tain siliceous white clays formed from the decay of the quartzites and schists, such as are found in Lancaster and Cumberland Counties. None have been reported from Berks County. At New Berlinville the Landis Brick Co. has a small brick yard using yellow residual clay in the manufacture of common brick.

The Triassic belt in the southern portion of the county should yield good brick shales in the areas where the shale is soft. Brickyards are successfully using similar material in other counties.

The hills of Chickies quartzite along the southern border of Berks County, northeast of Elverson, Chester County, may carry areas of residual white clays and sands as does Welsh Mountain near Narvon, Lancaster County. None have been reported.

Physical tests made on weathered Martinsburg shale, sample 338, near Mohrsville

Water of plasticity	25.7 percent
Linear drying shrinkage	3.9 percent
Time of slaking	3 minutes
Modulus of rupture	108 pounds to square inch
Maximum linear burning shrinkage	7.4 percent (at cone 1)
Fusion point	cone 11
Best burning range	cone 02 to 1
Firing color	salmon to good brick red
Suggested uses	brick

References to the geology of Berks County:

- Bascom, F., and Stose, G. W., Geology and mineral resources of the Honeybrook and Phoenixville quadrangles, Pennsylvania: U. S. Geol. Survey Bull. 891, 1938.
- d'Invilliers, E. V., The geology of the South Mountain Belt of Berks County: Pennsylvania Second Geol. Survey Rept. D 3, vol. 2, pt. 1, 1883.
- d'Invilliers, E. V., Limestone quarries, Berks County (west of Schuylkill River): Pennsylvania Second Geol. Survey Ann. Rept. for 1886, pt. IV, pp. 1554-1562, 1887.
- Willard, B., and Frazer, D. M., Guidebook to the geology near Reading, Pa.: Pennsylvania Topog. and Geol. Survey, Bull. G 15, 1939.

BLAIR COUNTY

Blair County lies between Cambria and Huntingdon Counties near the center of the State. Its western boundary is Allegheny Mountain, the high eastern edge of the plateau area. The mountain crest is made up chiefly of the heavy sandstones of the Pottsville and the Pocono series. In the upper portion of the Pottsville and in small areas of the lower Allegheny group there may be plastic or flint fire clays, excellent flint clays being present to the west in Cambria County. None were noted in Blair County. The red Mauch Chunk shales between the Pottsville and Pocono sandstones make up large

areas near the crest of the mountain. These could be used in brick manufacture although they are not generally in very accessible locations.

On the Allegheny Front, in descending succession, are the red Catskill shales and the gray sandstones and shales of the Chemung, Portage, Genesee and Hamilton divisions of the Devonian. These Devonian shales form the rolling foothills of a wide belt from the southern to the northern edge of the county, the area which lies west of Claysburg, Altoona, and Tyrone on Highway 220.

Similar shales occur between Hollidaysburg and Canoe Creek on Route 22. A sample of blue-gray shale (no. 306), taken from a roadside cut 4 miles east of Hollidaysburg on Route 22, showed fairly good plasticity and a low green strength. It fired a salmon to dark brown with a burning range from 1050° to 1125° C. It is not considered a very good brick shale. Testing shows water of plasticity, 17.5 percent; linear drying shrinkage, 3.3 percent; time of slaking, 5 minutes; modulus of rupture, 82 pounds per square inch; maximum linear burning shrinkage, 2.03 percent at cone 05; fusion point, cone 12; best burning range, cone 05 to cone 01.

The chemical analysis shows:

Loss of ignition ..	4.81	Al ₂ O ₃	20.65	MnO	.11
SiO ₂	58.94	CaO	1.11	P ₂ O ₅	.33
Fe ₂ O ₃	10.23	MgO	2.66		
TiO ₂	.94	Alkalies	2.40		

From experience in neighboring counties we believe that the Devonian shales furnish the best prospect for shales for brick making, and search for weathered shales within the Devonian areas would no doubt yield better material than the sample tested. The Devonian shale areas lie in excellent location for development.

Silurian shales form a belt through the central part of the county between the Helderberg limestone and the Tuscarora sandstone of the mountains. These shales are chiefly red and green and are frequently too limy for much use.

Residual clays overlying Ordovician and Cambrian rocks occur in two large areas of such outcrops; one, the Sinking Valley in the north-central part of the county south from Birmingham and Arch Spring; the other, Morrison Cove from Yellow Spring south through Williamsburg to Martinsburg.

In these areas there are many pockety deposits of white or light gray siliceous clay which are dug and used as refractory cements and linings in the furnaces in the steel industry.

In the Sinking Valley area no pits of these clays are opened in Blair County but several lie north of the county line in Huntingdon County. In the Morrison Cove area three pits have been opened.

These are the Woodbury Clay Company pit at Mines Station (Oremine) six miles south of Williamsburg; the Fair Valley Clay Company, two miles northeast of Martinsburg, and the Duncan pit at Ore Hill, four miles south of Roaring Spring. Of these the Woodbury Clay Company pit is by far the largest operation.

Oremine. The Woodbury Clay Company operates at Mines Station or Oremine, 6 miles south of Williamsburg. It is by far the largest operation on the Gatesburg clay. The pit is one mile southwest of Mines Station on the Springfield branch of the Pennsylvania Railroad. The workings form a veritable Grand Canyon some 2,000 feet long and 150 feet deep. Operations are conducted with a battery of three steam shovels, and locomotives and trackage carry the clay from the pit to a loading tippie on a standard gauge spur of the railroad.

In the pit, the upper 50 feet is made up of yellowish stony soil and chert with chimneys of white clay extending into it from below. Under this zone there is generally about 10 feet of white chert, then 40 or more feet of white or tinted clay in irregular pockets. With such large operations and by working in benches the different grades of clay may be kept separate and much of high quality obtained. The clay goes chiefly to steel mills but is said to be suitable also for paper-making, saggars, or white ware, but for these a washing plant would need to be installed. During good times 50 to 75 men are employed.

Prof. J. B. Shaw at State College tested three samples for the Geological Survey. No. 211, the best plastic; 212, sandy plastic; and 213, very sandy plastic. No. 211, the best grade, showed a burning range from 1100° to 1350° C. and fired to a light cream. The other grades fired to light to dark buff. The other tests follow:

No.	Water of plasticity	Shrinkage water	Pore water	Slaking	Linear air shr.	Volume air shr.	Fusion	Maximum lin. shr.	Modulus rupture
	%	%	%	min.	%	%	cone	%	lbs.
211	32.4	9.2	23.2	7	14.4	4.6	29	11.1	9
212	30.6	10.9	19.7	6	17.8	5.6	30	7.1	18
213	22.2	7.5	14.7	7	13.7	4.4	30	2.6	27

The United Clay Mines Corporation, of Trenton, N. J., opened a white clay pit one mile southeast of Oremine in 1940.

Martinsburg. The Fair Valley Clay Company of Altoona dug white clay two miles northeast of Martinsburg for several years. The pit is large and its walls show many varieties of clay, along with sand and iron ore. The clay was dug with a steam shovel and trucked two miles to the railroad at Martinsburg. A sample of the clay tested by

Shaw shows the following: Firing range, 1100° to 1350° C.; water of plasticity, 29.2 percent; shrinkage, water, 4.2 percent; pore water, 25.0 percent; slaking, 45 minutes; linear air shrinkage, 6.3 percent; volume air shrinkage, 2.1 percent; fusion cone, 27; maximum linear shrinkage, 5.1 percent at 1350° C.

This clay pit was worked out and in 1940 the company was digging white clay at an old iron ore mine one mile farther north. The clay is hauled by truck to Martinsburg and shipped by rail to steel mills in the Pittsburgh district, and to Illinois, West Virginia, and Canada.

No doubt other prospects of such clays will be uncovered and it may be well to remember: (1) That much preliminary prospecting must be done to determine the extent; (2) that the deposits are usually small and frequently badly discolored; (3) that although the clay may appear very white, it has not as yet been successfully used in china manufacture or in paper making but has value as a cement in steel mill furnaces.

Selected references to the geology of Blair County:

Butts, C. (and Swartz, F. M., Willard, B.), Tyrone Quadrangle: Pennsylvania Topog. and Geol. Survey, Atlas A 96, 1939.

Butts, Charles, Geologic Section of Blair and Huntingdon Counties: Amer. Jour. of Sci., fourth series, vol. 46, pp. 523-537, 1918.

Leighton, Henry, The White Clays of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. 112, 1934.

Platt, Franklin, The Geology of Blair County: Pennsylvania Second Geol. Survey Rept. T, 1881.

BRADFORD COUNTY

Bradford County lies along the New York State line west of Susquehanna County. It is a high, rolling plateau of Upper Devonian, Mississippian, and Pennsylvanian strata generally flat-lying but locally highly tilted. The whole of the county has been glaciated.

It is drained chiefly by the North Branch of the Susquehanna River which crosses it from Sayre to the southeast corner. The Lehigh Valley Railroad follows the Susquehanna River and a branch line extends south from Towanda. The Pennsylvania Railroad serves the western part of the county from Grover north to Fassett. The Susquehanna and New York Railroad extends southwest from Monroe. Many good highways serve the county, including Route 6 from east to west and Route 220 from north to south.

Pennsylvanian and Mississippian strata lie within two high synclinal mountain areas in the southwestern part of the county. The largest area is a high plateau of Pocono sandstone extending southwest from Monroe and South Branch. This is a great syncline with gentle dips on the south edge and steep dips near Leroy on the north

edge. Enclosed within the rim of Pocono sandstone between Shrader and Towanda Creeks is a basin of Pennsylvanian strata, the Pottsville sandstones overlain by small areas of Coal Measures, the Barclay coal basin. Fire clays and good shales are lacking. The isolated position is against development.

The second synclinal mountain lies north of Canton and west of Troy. It represents the eastern end of Bloss Mountain of Tioga County. The portion of it within Bradford County is chiefly Pocono and Pottsville sandstone, and there are no available clays or shales.

The Catskill shales and sandstones of the Upper Devonian, including the New Milford division of the Wayne County section, form high rolling areas in the extension of the synclines eastward. East of the Barclay syncline a large area of Catskill beds occupies much of the southwest corner of the county. These beds are in part red and gray sandstones and partly soft red shales. The softer and better weathered red shales might be used in brick making. Suitable shales occur 3 to 5 miles south of Monroe, and others 2½ miles south of New Albany along Route 220.

East of the Bloss Mountain syncline a belt of Catskill strata extends through Troy and Sylvania and east through Leona and East Smithfield, ending west of Ulster. The red shales might be developed in the vicinity of Troy.

East of the Susquehanna River, areas of Catskill strata, chiefly the New Milford flagstone beds, extend into the county from Susquehanna County.

The rest of the county in the anticlinal areas is underlain by Chemung shales and sandstones, the Susquehanna River flowing entirely in these beds. They are generally made up of thin sandstones interbedded with thin shale beds of gray to green color. The close interbedding of shale and sandstone makes it impossible to use them in brick making. Careful search might expose beds of gray or olive-green shale sufficiently thick to be workable.

Glacial drift is prominent in the county, especially along the valleys, some of which have deep deposits of well-sorted bluish clay free from boulders. In early days this glacial clay was used in small common-brick and tile plants, but it is seldom used at present. Bricks are now made from shales in larger plants. Glacial clays are very plastic, however, and if free from boulders or freed from boulders can be used to make various types of pottery, tile, and brick. Good deposits are limited in size and of a pockety character.

Selected references to the geology of Bradford County:

Sherwood, A. and Platt, F., Report of progress in Bradford and Tioga Counties: Pennsylvania Second Geol. Survey, vol. G, 1878.

Willard, B., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G. 19, 1939.

BUCKS COUNTY

Bucks County lies along the eastern border of the State, northeast of Philadelphia and Montgomery Counties. The Delaware River forms its entire eastern and southeastern boundary.

It is within the Piedmont province and chiefly in the Triassic lowland section. The extreme northern corner of the county is underlain by pre-Cambrian crystalline rocks and Cambrian quartzite and is a part of the Reading Hills. South from this area are the lowlands of the Triassic underlain by red shales and sandstones which have been intruded by dikes and great sheets of diabase. Across the lowlands in a northeast direction are three distinct hilly areas or low ridges rising from 600 to 900 feet above sea level. The southerly ridge is due to resistant shale in the Lockatong or middle division of the Triassic beds; the second ridge is due to shales hardened and baked by igneous intrusion; the third or northerly ridge is held up by a resistant diabase sill. Along the mid-eastern border of the county is a faulted and tilted block of Cambrian and Ordovician strata. The resistant Hardyston quartzite of the Cambrian rises as a sharp ridge, Buckingham Mountain, on the southeastern edge of the block, and to the northwest Cambrian and Ordovician limestones underlie a low area, Buckingham Valley.

West from the Delaware River north of Morrisville a narrow belt of pre-Cambrian gneisses and schists extends southwest along the southern boundary of the Triassic belt. These rocks are in part covered by terrace gravels, the Pensauken gravels.

South of these exposures are lowlands bordering the Delaware River in the great bend that it makes from Trenton to Philadelphia. The north side of the river is here a wide low area of pre-Cambrian rocks covered almost completely by a thin mantle of sands, gravels, and loams known as the Cape May formation.

The northern area of gneisses and quartzites may carry residual siliceous clays but in most places the residual material is a kaolinitic sand used as a sand. The Triassic strata are known as the Newark series. They consist of gently dipping red and green or gray shales and sandstones which are divided into three formations. The upper or Brunswick formation is 12,000 feet thick and contains the most of the soft red shales of the group; the middle or Lockatong formation 3,500 feet thick is more sandy and resistant; the lower or Stockton formation 3,500 feet thick is in part soft shale but more largely sandy beds.

The softer shales, especially in the Brunswick formation, make excellent brick and they could be used for brick or tile manufacture in many parts of the county, especially along the Delaware River. At

present (1938) one small plant, the Perkasio Brick Works, is using the Brunswick shales at Perkasio. One small pottery, the Moravian Pottery and Tile Works, is using the Stockton shales at Doylestown. At Southampton, Hyzer and Llewellyn operate a brick yard, using Stockton shale.

In Buckingham Valley, residual clays overlying the Cambrian limestones are plastic, red-burning clays suitable for small brick plants or small pottery operations.

The exposed pre-Cambrian gneisses, schists, and quartzites west from Morrisville are often weathered into stony residual clays, but no clays of value are known. Bordering the Delaware River above Morrisville and spreading over a wide plain below Morrisville are the Cape May terrace deposits. They are mainly sands and gravels with some silt but offer little possibility for brick making.

The valuable clays of the Tertiary and Cretaceous periods lie across the Delaware River in the coastal plain deposits of New Jersey.

Selected references to the geology of Bucks County:

Bascom, F. (et al.), U. S. Geol. Survey Geologic Atlas, Trenton folio (no. 167), 1909.

Bascom, F. (et al.), U. S. Geol. Survey Geologic Atlas, Philadelphia folio (no. 162), 1909.

Bascom, F. (et al.), Geology and mineral resources of the Quakertown-Doylestown District, Pennsylvania and New Jersey: U. S. Geol. Survey, Bull. 828, 1931.

Miller, B. L., Allentown Quadrangle: Pennsylvania Topog. and Geol. Survey Atlas 206, 1925.

CAMBRIA COUNTY

Cambria County lies east of Indiana County and west of Blair County. Its eastern boundary is, roughly, the crest of the Allegheny Mountains, or more properly the eastern edge of the Appalachian plateau. This area is rugged and wooded and rises to heights of 2,400 to over 2,700 feet above the sea. Its southwestern border is Laurel Hill, also 2,700 feet above sea level. North of the Conemaugh River, this ridge swings to the east of the county line and continues in a course past Nanty Glo with elevations of about 2,300 feet. North of this point it loses its identity as a ridge although as an anticlinal structure it continues on through Carrolltown and to the northwest of Patton. The northwestern corner of the county and the central belt between the two mountain masses is a rolling plateau averaging about 2,000 feet above sea level.

Drainage is practically all to the north and to the west. The southern half of the county is drained by the Little Conemaugh River, Stony Creek, and the Conemaugh; the west central part by Blacklick

Creek, and the northern part by Clearfield and Chest Creeks and the head waters of the West Branch of the Susquehanna River.

The main line of the Pennsylvania Railroad crosses the southern half of the county following the Conemaugh and Little Conemaugh Rivers through Johnstown. The Baltimore & Ohio Railroad follows Stony Creek to Johnstown. Branches of the Pennsylvania Railroad follow the south branch of Blacklick Creek to Ebensburg and continue north to Patton on Chest Creek. Other branches follow the Susquehanna, Chest Creek, and Clearfield Creek. The New York Central Railroad also serves a part of the northern area along Chest Creek. The William Penn Highway, U. S. 22, crosses the county through Ebensburg and Cresson.

The rocks of the county are sedimentary; in the various parts of the county about 1,750 feet of such strata are exposed, subdivided as follows:

	Feet	
Pennsylvanian	{ 100	lower part of Monongahela group
	{ 900	Conemaugh group
	{ 275	Allegheny group
	{ 200	Pottsville series
Mississippian	{ 175	Mauch Chunk series
	{ 1,000	Pocono series
Devonian	400	Catskill series

Over most of the county these rocks are but slightly folded. In Laurel Hill, however, a decided anticlinal structure is present with strong dips. Along the eastern border of the county dips are also strong, the beds dipping west or northwest away from the crest of the Allegheny Front. Between these two structures dips are gentle, the only other structure of much importance being the low Ebensburg or Viaduct antiline which extends from Sealp Level to Ebensburg and brings up the Mississippian rocks which appear between Mineral Point and South Fork on the Little Conemaugh River.

Shales suitable for the manufacture of brick or tile are found occasionally in the Catskill or the Mauch Chunk beds, and commonly in the Conemaugh and Allegheny groups; plastic and flint fire clays are confined to the Allegheny group and to the Mereer horizon of the upper part of the Pottsville series. The occurrence of these clays will be described by districts.

Northern district. That portion of the county north of an east-west line through Ebensburg and west of Clearfield Creek is a gently rolling region drained mainly by the West Branch of the Susquehanna River and by Chest Creek. The uplands are chiefly underlain by Conemaugh strata. Along the Susquehanna River the Allegheny group with its coals and clays is prominent; along Chest Creek the Allegheny group is present and also some of the underlying Potts-

ville series. The areas underlain by the Conemaugh strata are chiefly areas of shale with practically no workable coals or clays. The shales are, however, of good quality for brick making and make frequent outcrops. The only tests on these shales in the northern district were made on those used by the Patton Clay Manufacturing Co., the only brick company in the northern district. This plant is located at Patton and manufactures sewer pipe, paving brick, and face brick on a large scale. They use shale and clay from a pit on the hill west of the plant and also use Lower Kittanning clay hauled by truck from a mine about a mile up Chest Creek. The shale pit is on a high ridge of Conemaugh rocks and the shale is dug with an electric shovel and carried to the plant by cable and gravity plane. Section in quarry at Patton follows:

Feet

2	soil
2	sandstone and soil
3	weathered clay
10	shale (nos. 371, 372)
4	soft clay (no. 373)
4	hard blue clay shale (no. 374)

These beds are in the lower part of the Conemaugh group. Samples 371 and 372 represent respectively the main shale from the west end of the pit and a more weathered shale from the east end of the pit. They both have good plasticity and a low green strength. They fire to red to dark brown and have a firing range from cone 01 to cone 9 and they fuse at cone 17. The weathered shale (no. 372) is a trifle more plastic and may be burned to a good product at a slightly lower temperature than no. 371. They both are good shale for face brick and tile manufacture. No. 373, the soft clay, has good plasticity and fires to a cream to gray color with a firing range from cone 3 to cone 12. It fuses at cone 20. It is suited to the manufacture of face brick, sewer pipe or paving brick and from the tests it appears to be as good a clay as the Lower Kittanning clay. The hard blue shale (no. 374) has a fairly good plasticity. It fires pink to dark brown with a firing range from cone 3 to cone 12, and fuses at cone 18. It is suitable for brick manufacture. The Lower Kittanning clay (no. 370) has good plasticity and a low green strength. It fires to a gray to buff color with a burning range from cone 3 to cone 9, and fuses at cone 18. It cannot be classed as a fire clay but it is an excellent clay for face brick and sewer pipe manufacture. Various mixtures of the Lower Kittanning clay and the local clay and shale make a great variety of colors and products. These tests demonstrate the value of some of the Conemaugh shales and clays and there is no doubt much of this type of material in the Conemaugh areas of the county.

Coal is mined extensively in the valleys of Chest Creek and the Susquehanna. The principal coals mined are the Lower Freeport, Upper Kittanning, and Upper Freeport. In these valleys the Upper Kittanning carries a good clay from 3 to 6 feet thick. The other coals have less prominent underclays in the district and none are worked. Sample 353 is an underelay from below the Upper Freeport coal at Kinport in the extreme northwest corner of the county. This shows good plasticity and low green strength. It burned to a poor brown with a burning range from cone 3 to cone 9 and it fused at cone 15. It seems suitable for face brick or tile manufacture. This material was taken from the dump and is an indication of the possibilities of some of the unworked clays of this district. Probably other clays associated with the coals in the Barnesboro and Patton districts could be used in the manufacture of buff brick and possibly sewer pipe.

Northeastern townships east of Clearfield Creek. The townships of Reade and Dean lie east of Clearfield Creek and extend east almost to the crest of the Allegheny escarpment. They are served by branches of the Pennsylvania Railroad. The strata of the area are chiefly those of the Allegheny group, with smaller areas of Pottsville rocks along the east boundary and appearing along Clearfield Creek, Laurel Run, and Lost Creek. The area north of Fallentimber and Glasgow is chiefly underlain by Conemaugh strata. The strata form a part of the first synclinal coal basin west of the Allegheny Front. Coals mined include the Brookville, Lower Kittanning, Upper Kittanning, and Lower Freeport. Shales are abundant for brick making, especially in the Conemaugh rocks, but the main interest lies in the flint clay found near the base of the Allegheny group or near the top of the Pottsville series. Clay from this horizon is being mined near Blandburg and Dean. Both areas lie about 3 to 4 miles back from the crest of the Allegheny Front.

At Blandburg the Harbison-Walker Refractories Co. operates a well-equipped fire-brick plant. Both plastic and flint clay are obtained from their mines three-quarters of a mile southwest of the plant and carried to it by tram. The bed of clay averages 4 feet thick and varies in proportion of flint clay to plastic from 1:3 to 3:1. The clay bed is overlain by 20 to 30 feet of shales over which is a 36-inch bed of coal, supposedly the A or Brookville coal. This coal though somewhat dirty, is used by the company. Flint clay from Dean is also shipped in to supplement the local clay. The local flint clay is known as "Cambria" clay and is represented by sample no. 368. This of course has poor plasticity and low green strength. It fires white to gray with a firing range from cone 02 to cone 13. It fuses at cone 34. Its high fusing point and the high alumina content (40.06 percent)

as seen in the analysis, give it a high rating as a flint clay. The plastic clay from the same bed is represented by no. 369. This has good plasticity and a low green strength. It fires cream or gray with a firing range from cone 3 to cone 9 and fuses at cone 32. It is an excellent plastic clay for the manufacture of refractories. The plant is located on the Bellwood branch of the Pennsylvania Railroad over which shipments of brick and clay are made.

The other active district lies two to three miles east from Dean, a station on the railroad along Clearfield Creek. The mines are reached by long tram roads from Dean and the clays are all shipped from Dean, no brick being made in the district. Two companies mine and ship clay, the Harbison-Walker Refractories Co. and the Johnstown Mining Corporation. The bed of clay mined averages $3\frac{1}{2}$ feet thick and varies from 2 to 6 feet thick. It is chiefly flint clay and the mineable flint clay varies from 18 inches to 4 feet in thickness. The bed is overlain and underlain with sandstone and is correlated with the Mercer horizon, although it may be lower Allegheny clay. The average of the flint clay in the Johnstown Corporation mines is indicated by sample no. 367. This has a fair plasticity and a low green strength. It fires to a cream color with a firing range from cone 02 to cone 13 and it fuses at cone 34. It is a high-grade flint clay well suited to the manufacture of refractories. It is usually known as the Dean clay. The Dean and the Blandburg clays resemble each other closely and probably represent the same bed although correlation is difficult. It is evident however that in this corner of the county there is a bed or beds of an unusually good flint clay and there seems a chance for considerably more development.

District east and southeast of Ebensburg. The Wilmore syncline passes through Wilmore and near Munster. Under the effect of this structure the surface rocks are of Conemaugh age over most of the district, including a triangle extending east from Ebensburg to Gallitzin, south through Cresson, Cassandra, and Summerhill, and back to Ebensburg. As the strata rise eastward toward the Allegheny Front, the Allegheny group comes to the surface in a narrow band which enters the county east of Cresson and passes southwest on the east of Lilly, Puritan, Beaverdale, and Dunlo. East of this belt Pottsville, Mauch Chunk, and Pocono strata appear in succession and the eastern border of the county lies mostly in the latter series.

The Pocono and Mauch Chunk beds are of little interest to the clay worker. The Pottsville at Bennington is made up of the Homewood sandstone 15 feet thick, underlain by about 15 feet of clay, shale, and coal of the Mercer horizon, and this underlain in turn by the Connoquenessing sandstone 80 to 100 feet thick. The Pottsville belt

enters from Blair County 4 miles east of Lilly and passes southwest past Martindale and Onnalinda. Rock Run, Christies Hollow, Bens Creek, Trout Run, and the south branch of Little Conemaugh River cut deeply into Pottsville rocks. That part of the Pottsville of interest for its clays is the Mercer horizon near the top. Coal mined at the Eleanora mine at Martindale and a coal mined above Lloydell at railroad grade near the tipple of the Cambria mine may be of the Mereer horizon.¹ These points and also one mile east of Bens Creek would be logical points to look for good flint clay or plastic clay in the Pottsville series. In this zone east of and below the outcrops of the Lower Kittanning coal, either in the lower Allegheny group or in the upper Pottsville, are usually found the good clays all along the Allegheny Front. West of the Pottsville outcrop the Allegheny group appears in a belt from one to three miles wide. Mining is done mainly on the Lower Kittanning and the Upper Freeport coals and the greatest activity is from Lilly to Bens Creek on the Pennsylvania Railroad and along the valleys east from these towns; in the Puritan-Martindale area; at Beaverdale and Onnalinda; and at Dunlo. Little is known concerning the underclays of this area. Butts notes the presence of some flint clay below the Upper Freeport coal near Dunlo; a clay under the Clarion coal on Bens Creek one mile east of Myra; several feet of clay below the Upper Kittanning coal on Trout Run.

The Conemaugh strata of the district consist mainly of shales and sandstones. The shales are abundant and are of good quality for brick making. About 100 feet above the Upper Freeport coal is the Gallitzin coal. Below it a clay was stripped south of Gallitzin and used for making brick for the first Gallitzin tunnel. In the cut east of Cassandra a clay bed is seen in the Mahoning sandstone horizon above the Upper Freeport coal. Experience elsewhere has shown that in this lower 100 feet of Conemaugh strata, clay layers occur which may be low grade fire clays or plastic clays suitable for buff brick. Such clays have been used from the lower Conemaugh strata at Johnstown and have been noted at Wehrum in Indiana County.

No clay or shale is now being worked in this southeastern district.

District west and southwest of Ebensburg. The area southwest of Ebensburg includes the Laurel Hill region along the western border of the county, the coal mining region along the south branch of Blacklick Creek, and the Johnstown district along the Conemaugh and Little Conemaugh, and on Stony Creek. The deep valleys of the Conemaugh and Little Conemaugh Rivers and Stony Creek have been developed into industrial areas of great importance, with Johnstown, at the junction of these three streams, as the center.

¹ Butts, C., Description of the Ebensburg Quadrangle: U. S. Geol. Survey Geol. Atlas, Ebensburg folio (no. 133), 1905.

At the west end of Johnstown in the steep bank of Stony Creek, the Upper Kittanning and the Upper Freeport coals are well exposed under about 200 feet of the Conemaugh group. In the Conemaugh strata brick shales are common and there is probably also some of the same clay found on the East Main Street hill and once used by the Johnstown Pressed Brick Co. The Upper Kittanning coal is mined by the Cambria Steel Co. at the Rolling Mill mine but no use is made of the clay as it is probably thin and impure, like that farther west on the railroad. West of Cambria the same coals border the valley and appear along the railroad. Just west of the plant of the Haws Refractories Co. along the railroad the following section is present:

Feet

10	shale
4	sandstone in thin layers
2	coal with 8 in. parting near top
2	clay
1-2	nodular limestone
3	clay
8-12	shale

This coal is the Upper Kittanning. The clays seem to be of poor quality. The Haws Refractories Co. at this point manufactures fire brick and obtains its plastic clay from the mine at Cooperdale and its flint clay from Dean. Formerly the Lower Kittanning clay was mined at the plant through a shaft but the clay became too sandy and is no longer used.

The Cambria Steel Co. operates a small brick yard at Cambria, making common brick for their own use. Their shale is obtained by rail from Prospect Hill, east of the plant. It is a lower Conemaugh shale lying about 100 feet above the Upper Freeport coal.

On the north bank of the Conemaugh, opposite Cambria, on the road leading to Pleasant Hill, there are various exposures of the lower Conemaugh rocks. The clays seen were badly contaminated with limestone nodules. About half a mile up this road there is a 12-foot cliff of dark shale carrying marine fossils and probably representing the Brush Creek shale. This shale (no. 359) shows good plasticity and a high green strength. It fires red to dark brown with a firing range from cone 01 to cone 9. It fuses at cone 14. It seems suitable for the manufacture of brick or tile.

At Cooperdale the Lower Kittanning coal and clay appear above stream level and are mined at the plant of the Haws Refractories Co. at that point. Entrance is made by slopes from the rear of the plant. The clay under the coal is from 4 to 10 feet thick. This clay (no. 356) has good plasticity and fair green strength. It fires gray buff with a firing range from cone 3 to cone 12 and it fuses at cone 29. This clay is well suited to the manufacture of buff brick, sewer pipe or fire brick. The company uses it with flint clay for the manufacture

of fire brick at both plants. Just west of this plant an outcrop shows the following section:

Feet	
2	shale
1	coal
8	clay (no. 357)
2	coal
20	heavy sandstone

These coals may represent the Clarion and the Brookville coals or may be two Clarion coals. The clay between them (no. 357) has good plasticity and low green strength. It fires buff to dark gray with a firing range from cone 3 to cone 12 and it fuses at cone 26. It might be used in the manufacture of buff face brick, sewer pipe, or as a bond clay in refractories. It is easily accessible.

Across the river from this locality and just north of Sheridan is the plant and quarry of the Triangle Clay Products Co. The section in the quarry follows:

Ft.	in.	
3		yellow soil and boulders.
3		heavy white sandstone (Homewood)
0-3		whitish clay
0	9	coal
18		brown to gray shale (no. 354)
1	3	slaty coal
14		clay (no. 355) with stigmaria roots and cylindrical concretions.

The dip is strongly east carrying these beds, probably of Mercer age, under the adjoining mine and plant of the Haws Refractories Co. at Cooperdale. The shale (no. 354) shows fair plasticity and low green strength. It fires to a light to dark gray color with a firing range from cone 6 to cone 9. It fuses at cone 17. It is well suited to brick manufacture. The clay at the base of the section (no. 355) has good plasticity and a low green strength. It fires to a dark buff to gray with a range from cone 6 to cone 12 and it fuses at cone 18. It is therefore not a true fire clay but is an excellent clay for face brick making. The materials are taken out with a steam shovel, trammed to the plant, ground by roll crusher and dry pan and molded by a Steele electric-drive auger machine. Burning is done in 10 round coal-fired kilns. Face brick are made in a variety of colors, using the shale for the darker brick and the clay for the lighter shades.

Northwest from this point the river has cut a deep gap through Laurel Hill and in the next two miles there are exposed in turn, Mauch Chunk red shales, Pocono sandstones, and Catskill red shales and sandstones. The red shales of the Mauch Chunk and of the Catskill are very much alike, an alternation of soft red shales, green shales and clays, and red and green sandstones. The Mauch Chunk at other localities (see Fayette County) has proven to be suited to brick

making and no doubt could be used for this in the Laurel Hill area. The Catskill red shale and clay crop out near the center or axis of the anticline near the Indiana County border. Sample 358 represents its softer phase as seen one mile east of the Indiana County line along the road. This clay shows good plasticity and fair green strength. It fires red to brown with a firing range from cone 04 to cone 3 and it fuses at cone 15. It is suited to the manufacture of red face brick or tile.

South from Johnstown up Stony Creek. Up Stony Creek south from Johnstown, the Upper Kittanning and Upper Freeport are the principal coals exposed along the cliffs; the higher banks and the uplands carry strata of the lower Conemaugh. South of Moxhom the coals descend to stream level and in the big loop at the corner of Somerset County the Conemaugh rocks are at stream level. Thence east towards Krings the strata rise again rapidly and at Krings the Lower Kittanning coal is exposed. Just above this point the Pottsville series appears and the Mercer horizon is exposed. Near the mouth of Paint Creek the Mauch Chunk red beds are seen. No clays or shales have been worked in this area but there is clay below the Lower Kittanning which might be worked and there is a possibility of finding good clay or shale in the Mercer beds although both shale and clay seem here to be thinner than usual. The red shale of the Mauch Chunk would also make good brick. This district lies along the Baltimore & Ohio Railroad and is therefore readily accessible.

East from Johnstown. Just east of Johnstown up east Main Street, is a prominent hill composed of the upper portion of the Allegheny group and the lower portion of the Conemaugh group. On this hill stands the plant of the Johnstown Pressed Brick Co., idle for many years. This plant made fine-textured buff and red face brick. Their chief difficulty seems to have been the location which made transportation of their finished products very difficult. The Upper Freeport coal was mined near the plant. Many parts of the 200 feet of Conemaugh strata above the coal have been used in brick making. The portions used most were a bed of plastic and flint clay about 70 feet above the coal bed and red and green shales about 150 feet above the coal. The red and green shales of the upper quarry have the following section:

Feet	
5	heavy sandstone capping
20	red and green shale
1	coaly streak
3	gray clay
20	red and green shale
5	yellow nodular sandy rock
10	mottled red and green shale
10	red and buff clay and shale

These were sampled as no. 351, eliminating the sandstone masses. This sample shows a fair plasticity and green strength. It fires red to dark brown with a firing range from cone 3 to cone 9 and fuses at cone 14. It is a good face-brick and tile clay. Below the shale beds thick sandstones appear and continue down to the level of the kilns with some intervening shaly layers and clay beds now much obscured. The clay bed mentioned by Phalen¹ lies just above the kilns and is about in the middle of the sandstone beds perhaps 50-70 feet above the Upper Freeport sandstone. In 1933 little flint clay could be found; it appeared to be an impure plastic clay. On the main road above and east of the plant over 5 feet of this clay is again exposed. This clay (no. 352) has fair plasticity and green strength. It fires dark gray with a firing range from cone 01 to cone 9 and fuses at cone 16. It is suited to the manufacture of face brick. Phalen makes note of several localities around Johnstown where either plastic or flint clay has been found between 50 and 100 feet above the Upper Freeport coal. These would be similar to the clays found in the Mahoning and Brush Creek positions elsewhere. None of these is worked in Johnstown and it is unlikely that any good flint clay exists at that position.

Continuing up the valley of the Little Conemaugh River to Woodvale we find the Upper Kittanning coal cropping out prominently along the railroad. Just west of Woodvale the following section was seen along the railroad:

Feet	
8	sandstone
3	shale
3	coal (U. K.)
3	limestone
8	clay
20	dark, jointed shales

The clay looked unpromising and no sample was taken. At Woodvale Hiram Swank's Sons, Inc., have a fire brick plant using flint clay from Clearfield County and plastic clay from a mine in the Lower Kittanning bed a quarter of a mile east of the plant on the south side of the river. The clay varies from 3 to 6 feet in thickness and averages perhaps 4 feet though it is very irregular. This clay (no. 360) has good plasticity and a low green strength. It burns to a tan to gray with a firing range from cone 3 to cone 9 and fuses at cone 28. It makes a very satisfactory clay as a bond with the flint clay and it might also be used alone in the manufacture of buff face brick. Beyond this point the coals rise rapidly above the stream and the stream flows on Pottsville and Mauch Chunk or Pocono beds.

¹ Phalen, W. C. and Martin L., Mineral Resources of Johnstown, Pa., and vicinity: U. S. Geol. Survey Bull. 447, pp. 115-116, 1911.

From Mineral Point to South Fork the Pottsville series carries, in the Mercer horizon, a very important flint and plastic clay bed which has been worked for many years. Phalen¹ describes the occurrence of the clays in this region and gives a section of the clay in the J. H. Wickes mine as follows:

Ft.	in.	
		heavy sandstone roof
3	6	plastic clay (no. 365)
0	2	coal
4	6	flint clay (no. 364)
		sandstone

At Mineral Point this clay is 300 feet above the river and it is carried by inclines down to the railroad. The bed dips toward the east and reaches rail level at South Fork. This bed of flint clay was actively worked some years ago by the South Fork Fire Brick Co., who operated a well-equipped fire brick plant at South Fork. The mine was one mile west of the plant. The clay consists of 2 to 4 feet of plastic clay underlain by 2 to 5 feet of flint clay. The flint clay (no. 364) fires to a light cream color with a firing range from cone 3 to 13 and it fuses at cone 34. It is a very high-grade flint clay. The plastic clay (no. 365) has good plasticity and a low green strength. It fires buff to gray with a firing range from cone 3 to 13 and fuses at cone 29. It is also a high-grade plastic fire clay and makes an excellent bond.

At the bridge at South Fork the plastic Mercer clay 6 feet thick can be seen in a poor outcrop. To the east it drops below the river as do also the beds of the Allegheny group. East of South Fork Station 0.8 mile an interesting exposure shows 15 feet of clay of which one foot, about six feet from the base, is a flint clay. The whole is underlain by about 8 feet of sandstone. The average mixture, including the flint clay, is no. 366. This shows fairly good plasticity and low green strength. It fires to buff to gray with a firing range from cone 02 to 13 and fuses at cone 20. It might be used for low-grade refractories or for buff brick. It lies along the railroad, so is very accessible. It probably is another example of a lower Conemaugh clay. East from this point the strata are all of Conemaugh age through Summerhill and Wilmore. North over the uplands to Ebensburg, Conemaugh shales predominate and the same is true south from South Fork to Elton. Nothing of special interest to the clay worker is to be seen in these areas.

Nanty-Glo and Vintondale district. The coals mined in this district are chiefly the Lower Freeport and the Lower Kittanning, 150 feet apart. The Lower Kittanning bed has below it a clay from 3 to 5 feet thick, but this has never been used. Shales are abundant in the

¹ Phalen, loc. cit. pp. 121-123.

Allegheny group. One mile east of Vintondale a 15-foot bed of brown shale of good quality was noted. It probably overlies the Middle Kittanning coal. Along the railroad east of Vintondale station a section shows:

Feet	
10	sandstone
20	brown and black shale
3	coal
2	coal with binders
5	clay to railroad (no. 375)

This coal is probably the Middle Kittanning. The clay (no. 375) has good plasticity and fair green strength. It fires cream or gray with a firing range from cone 01 to 13 and fuses at cone 30. This is apparently a very good plastic fire clay with a long burning range. It is in excellent position for working and could be developed alone or in conjunction with the overlying shales.

Summary. Summarizing the clay possibilities of the county, it may be pointed out that the Mercer horizon of the Pottsville or a horizon just above at the base of the Allegheny group furnishes all the good flint clay worked. None of the flint clay horizons mentioned in the early reports have materialized as of importance. The Mercer horizon also furnishes good shale and clay for brick making. The coal of the Allegheny group which furnishes the best plastic clay is the Lower Kittanning, although the Middle and Upper Kittanning and others show some prospects. Shales and clays suitable for brick making lie in the lower 100 feet of the Conemaugh group. The upper part of the Conemaugh group carries much shale but no good clays.

In 1937 three well-equipped fire brick plants were in operation in the county, one sewer pipe plant, one plant manufacturing face brick, and three clay mines not connected with plants. Employed in these plants and mines were 740 men.

Localities from which samples of Cambria County clays were obtained

351. Shale. Conemaugh group. Johnstown Pressed Brick Co., east Johnstown.
352. Plastic clay. Conemaugh group. Johnstown Pressed Brick Co., east Johnstown.
353. Plastic clay from Upper Freeport bed, mine dump. Kinport.
354. Shale, Mercer bed. Triangle Clay Products Co., Sheridan.
355. Plastic clay. Mercer bed. Cambria Clay Products Co., Sheridan.
356. Plastic clay. L. Kitt. bed. Haws Refractories Co. mine, Cooperdale.
357. Plastic clay. Clarion (?) bed. Just west of Haws plant, Cooperdale.
358. Red clay. Catskill series. West of Cooperdale, near Indiana County line.
359. Shale. Brush Creek bed. Pleasant Hill road, north of Cooperdale.
360. Plastic clay. L. Kitt. bed. H. Swanks mine, Woodvale.
364. Flint clay. South Fork Fire Brick Co., 1 mi. west of South Fork.
365. Plastic clay. South Fork Fire Brick Co., 1 mi. west of South Fork.

366. Flint and soft clay. 0.8 mi. east of South Fork on railroad.
 367. Flint clay. Haws Refractories Co. mine, 3 miles east of Dean.
 368. Flint clay. Harbison-Walker mine, Blandsburg.
 369. Plastic clay. Harbison-Walker mine, Blandsburg.
 370. Plastic clay. L. Kitt. bed. Patton Clay Mfg. Co., Patton.
 371. Shale. Conemaugh group. West end of pit, Patton Clay Mfg. Co., Patton.
 372. Shale. Conemaugh group. East end of pit, Patton Clay Mfg. Co., Patton.
 373. Plastic clay. Conemaugh group. Patton Clay Mfg. Co., Patton.
 374. Hard blue clay. Conemaugh group. Patton Clay Mfg. Co., Patton.
 375. Plastic clay. M. Kitt. bed. $\frac{1}{2}$ mi. east of Vintondale on railroad.

The following clay analyses are from Pennsylvania Second Geol. Survey, vol. HH, 1875:

- P 1. Clay under Johnstown limestone. p. 148.
 P 2. Clay under Lower Kitt. coal at Johnstown. p. 148.
 P 3. Flint clay, near viaduct, South Fork. p. 147.

The following analyses are from U. S. Geol. Survey, Bull. 447, 1911:

- M 1. Plastic clay. L. Kitt. bed. Green Hill mine, Citizens Coal Co., Johnstown. p. 118.
 M 2. Plastic clay. L. Kitt. bed. A. J. Haws & Sons mine, Johnstown. p. 118.
 M 3. Shale. Upper shale, Johnstown Pressed Brick Co., Johnstown. p. 120.
 M 4. Shale. Lower shale, Johnstown Pressed Brick Co., Johnstown. p. 120.
 M 5. Shale and clay. Mercer beds. B. H. Campbell quarry, Sheridan. p. 121.
 M 6. Flint clay. A. J. Wickes mine, South Fork. p. 122.

Physical tests of Cambria County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point cone	Best burning range—cones	Firing color	Suggested uses
351	20.1	4.8	5	264	7.0	4	14	1-6	Red to dark brown	Face brick and tile
352	18.7	2.7	7	283	6.2	4	16	02-6	Dark gray	Face brick
353	19.0	1.7	10	135	6.7	6	15	1-6	Dirty brown	Brick and tile
354	21.0	3.2	5	109	7.2	9	17	4-6	Light to dark gray	Brick and tile
355	27.0	2.4	6	112	6.5	9	18	4-9	Dark buff to gray	Buff brick and tile
356	30.6	5.6	5	271	6.8	6	29	1-9	Gray buff	Buff brick, sewer pipe
357	21.1	2.9	4	135	7.4	9	26	1-9	Buff to dark gray	Face brick and tile
358	21.0	5.2	6	269	6.1	1	15	03-1	Red to brown	Red brick and tile
359	26.4	5.7	4	378	8.7	4	14	02-6	Red to dark brown	Brick and tile
360	21.8	7.4	8	198	5.5	4	28	1-6	Tan to gray	Buff brick, no. 2 refractories
364	25.0	4.2	4	126	8.1	11	34	1-11	Light cream	Refractories
365	23.5	5.0	4	184	7.8	9	29	1-11	Buff to gray	Refractories
366	19.6	3.5	4	130	5.8	11	20	02-11	Buff to gray	Refractories
367	21.0	3.0	2	72	6.6	11	34	02-11	Cream	Refractories
368	27.6	2.7	1	30	6.6	11	34	02-11	White to gray	Refractories
369	24.3	4.3	5	117	7.7	9	32	02-11	Cream to gray	Refractories
370	20.6	4.8	5	182	5.0	6	18	1-6	Buff to gray	Brick and tile
371	19.8	3.9	6	139	7.1	6	17	1-6	Red to dark brown	Brick and tile
372	28.3	5.2	9	102	8.3	6	17	02-4	Red to dark brown	Brick and tile
373	16.5	4.2	—	—	6.5	9	20	1-9	Cream to gray	Face brick, paving brick, sewer pipe
374	18.0	3.1	—	—	5.1	6	18	1-9	Pink to dark brown	Brick and tile
375	21.3	5.4	5	243	6.8	11	30	02-11	Cream to gray	Refractories

Chemical analyses of Cambria County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃	
351	6.73	55.00	6.95	1.84	21.56	.56	.19	.34	2.47	.00	.62	.63	
353	5.89	61.25	7.63	1.16	20.40	.72	2.36	.20	.86	.02	.08	.09	
354	6.86	61.96	4.01	.26	21.06	.05	1.25	2.15	.75	.22	.23	—	
355	6.04	61.49	7.48	.21	21.48	.55	2.28	—	—	.03	.07	.13	
356	8.25	55.75	2.67	.96	27.39	.50	.85	1.98	.75	.02	Tr	Tr	
358	4.22	60.32	18.32	1.09	7.18	.53	.20	—	—	—	.10	—	
360	7.30	59.83	2.35	.89	26.29	.35	.91	1.10	.78	.04	.49	.91	
364	13.38	44.02	2.87	1.87	37.14	.42	.20	2.09	.57	.01	.15	.20	
365	7.60	56.98	4.65	.91	26.40	.73	1.08	2.46	1.32	.03	Tr	Tr	
366	6.52	64.02	3.49	.60	24.17	.47	.51	—	—	.03	.23	.21	
367	13.31	41.63	2.39	.00	38.03	.75	.98	—	—	.03	.02	—	
368	14.63	41.17	2.11	.00	40.06	.62	—	—	—	.15	.02	—	
369	9.55	66.81	1.10	.39	16.64	—	—	—	—	.14	—	.18	
370	7.24	60.27	3.83	.17	25.02	.38	1.84	2.27	4.48	.03	.10	.17	
371	5.76	61.45	7.32	.22	21.15	.55	2.30	1.26	—	.02	.09	.13	
373	5.83	63.39	2.51	.89	23.83	.40	1.57	2.26	—	.02	.19	.18	
374	5.61	63.19	7.35	1.04	18.52	.63	2.72	.74	1.13	.03	.09	.19	
375	8.64	53.26	2.19	1.61	26.39	3.23	2.41	—	—	.12	.14	.20	
P. 1		71.98	2.21		26.29		.44			MnO ₂			
P. 2	5.83	68.82	2.79		20.85	.82	.23			.32			
P. 3	12.65	45.42	3.33		36.80	.87	.45			.66			
M 1	6.50	65.90	1.60	1.20	20.30	.09	.66	.34	2.98	.48			
M 2	6.40	66.40	1.68	1.00	19.80	.10	.61	.30	3.24				FeO
M 3	12.24	51.32	6.94		24.39	.70	1.73	.23	1.09	.14		Tr.	1.43
M 4	6.39	64.29	5.74		17.95	.46	1.30	.35	1.80	Tr.		Tr.	1.63
M 5	7.72	62.86	5.19		18.85	1.42	.98	.06	2.59	.37		.11	
M 6	13.52	44.30	1.40		38.31	.82	.59	.22	.17	.10		Tr.	.71

Selected references to the geology of Cambria County:

Butts, C., U. S. Geol. Survey Geol. Atlas, Ebensburg folio (no. 133), 1905.

Campbell, M. R. (and Clapp, F. G. and Butts, C.), U. S. Geol. Survey Geol. Atlas, Barnesboro-Patton folio (no. 189), 1913.

Phalen, W. C., U. S. Geol. Survey Geol. Atlas, Johnston folio (no. 174), 1910.

Phalen, W. C. (and Martin L.). Clay and shales of southwestern Cambria County, Pa.: U. S. Geol. Survey Bull. 315, pp. 344-354, 1907.

Phalen, W. C. (and Martin L.). Mineral resources of Johnstown, Pa., and vicinity: U. S. Geol. Survey Bull. 447, 1911.

Platt, F. (and Platt, W. G.). Report of progress in the Cambria and Somerset District of the bituminous coal field of western Pennsylvania. Pt. 1, Cambria: Pennsylvania Second Geol. Survey Rept. HH, 1877.

Sisler, J. D. Bituminous coal fields of Pennsylvania, Pt. 2: Pennsylvania Topog. and Geol. Survey Bull. M 6, Pt. 2, 1926. Pp. 95-125 describe the coals of Cambria County.

CAMERON COUNTY

Cameron County lies east of Elk County and south of McKean County. It is in the main a rugged wooded plateau with elevations of about 2,000 feet, deeply dissected by Sinnemahoning Creek and its branches. This stream drains west of the county south into the West Branch of the Susquehanna River. The exposed strata amount to about 2,000 feet and are chiefly sandstones and sandy shales. Their sequence is as follows:

	Feet
Allegheny group	200
Pottsville series	200
Mauch Chunk shales	50
Pocono series	700
Catskill red beds	500
Chemung shales	350
	2,000

These sedimentary rocks are gently flexed into a series of anticlinal and synclinal folds, the axes of which cross the county in a north-east-southwest direction. In the two main synclinal areas the Allegheny group, with coals and clays, caps the higher hills, making small synclinal coal basins. One of these crosses the county between Emporium and Cameron. The other lies in the northwestern corner of the county. In the intervening anticlinal areas the strata are chiefly Pottsville and Pocono sandstones.

The following description begins with the lowest exposed strata:

Chemung group. Only the upper portion of the Chemung group is exposed and this only in the deeper valleys around Emporium. The Chemung strata extend several miles up West Creek, Driftwood Branch, Portage Creek and down the Sinnemahoning from Emporium. They are chiefly flaggy stones and bluish or olive-green shales. Shales of the Chemung are exposed a few miles west of Emporium on the road to St. Marys and also north toward Sizerville. Some might be selected of sufficient value for brick making but generally they are too sandy.

Catskill formation. Above the Chemung and forming the lower portion of most of the larger stream valleys in the county are the reddish Catskill strata. These range from 350 feet in the northern part of the county to 500 feet in the south. They are generally red and green shales and reddish sandstones. Good exposures of these shales are seen on the St. Marys-Emporium road, 3 miles east of the Elk County line; south of Cameron on the highway; and west from Driftwood. The softer shales are used in other counties for brick making but are not utilized in Cameron County. Their accessibility

with respect to railroad and highway along the Sinnemahoning is to their advantage.

Pocono series. Overlying the red beds of the Catskill formation are the gray sandstones and shales of the Pocono. Their thickness ranges from 550 to 700 feet. They are bounded above by the thin reddish Mauch Chunk shales. The two formations make up the middle slopes of most of the valley walls. The greater part of the Pocono is thin-bedded sandstone. Only small amounts of shale are present, and the series seems to present little possibility for brick making materials. Opposite Canoe Run the hill shows 349 feet of such sandstones and flagstones from river level up to the Mauch Chunk formation.

Mauch Chunk formation. The Mauch Chunk is thin and generally reddish shales. Its thinness and its height above stream level preclude its use in brick making.

Pottsville series. Above the Mauch Chunk band of Mississippian age, the lower Pennsylvanian appears in the Pottsville series. In McKean and Elk Counties the average Pottsville section includes:

	Feet
Johnson Run sandstone	50
Alton coal group	26
Kinzua Creek sandstone	48
Marshburg coal and clay	5
Olean conglomerate	55

The section in Cameron County is similar but the sandstones in some places are very shaly and the Marshburg coal may be absent. The Pottsville series is the resistant sandstone which makes much of the plateau top throughout the county. The only portion of it of interest for its clays or shales is the Alton group which is probably equivalent to the Mercer group. This group ranges from 20 to 40 feet in thickness and is generally made up of three or four thin coals and their clays and shales. The upper coal is known as the Upper Alton or Star vein. The others are the Middle and Lower Alton. Opposite Canoe Run in the steep section the Alton group is as follows:

	Ft.	in.
Coal (Star vein)	1	0
Sandstone	0	6
Shale	3	0
Coal	0	3
Shale	8	0
Coal	0	3
Plastic, iron-stained clay	4	0
Coal	0	9
Sandy clay	4	0

The under clays of the Alton coals are of fire clay appearance but have not been tested or utilized.

Allegheny group. On the higher hills above the Pottsville sandstones there are small areas or basins of the Allegheny group. The

coals are mined in a small way and some use has been made of the accompanying clays.

The group presents the best possibility of any of the strata for clay and shale development. A generalized section shows:

	Feet
Shale or sandstone	20
Dagus (Lower Kittanning) coal	4
Fire clay	2
Shale and sandstone	30
Coal (Clarion or Scrubgrass)	3
Clay	2
Shale	50
Clermont (Clarion or Brookville) coal	5
Fire clay	3

The Dagus and the Clermont coals have been mined locally and under each is a clay which might be of value.

Two miles north from Cameron on the high divide between Sinnemahoning Creek and Black Coal Branch near Calder, the Penn Block Paving Brick Company operated a brick plant about 1917-19, manufacturing paving brick and block. The section shows:

	Feet
Sandstone	10
Gray brown thin shales	25
Hard sandstone	$\frac{1}{4}$
Coal	$2\frac{2}{3}$
Gray plastic clay with sandy lenses	3+

This coal is 342 feet above Sinnemahoning Creek and probably is the Clermont bed. For brick making, mixtures of the shale and plastic clay were used. A sample (no. 243) of the plastic clay showed good plasticity and low green strength. It fired to a cream to gray with a firing range of 1000° to 1200° C. It fused at cone 27 (2921° F. or 1605° C.) and seemed suited to the manufacture of face brick or fire brick. It indicates that there are possibilities of developing fire clays or buff burning face brick clays in the under clays of the region although their high altitude may be against them.

Up Sterling Run, Southern Branch and near Houston school on road to Dents Run a coal, probably the Clermont, has been mined. At the Fredrickson mine a twin seam of coal has been mined with about one foot of clay parting. This parting was sampled as no. 245. It lies in Elk County and is described there. It proved to be a highly refractory clay suited to fire brick manufacture.

Nearby on the A. F. Anderson property prospecting has been done on a flint clay 4½ to 6 feet thick which underlies a 30-inch coal (the Clermont?). The coal is said to lie 140 feet above the Mauch Chunk red beds (encountered in drilling) and 30 feet above a bottom coal (probably the "Star" bed). At the time of visit (1933) the property was controlled by A. C. Hau, of Kersey. This flint clay (no. 242) was non-plastic. It fired light cream with a firing range 1000° to

1350° C. It fused at cone 31 (3056° F. to 1680° C.) and is an excellent flint clay for refractories manufacture. This was the only flint clay seen in the county.

The Clermont coal crops out in the western part of the county north of Beechwood. A mine on the Logan property shows 2 feet of coal bottomed by 3 feet of sandy clay (sample no. 246). This clay shows good plasticity and burns to cream to gray with a firing range of 1000° to 1200° C. It fuses at cone 20 (2786° F. or 1530° C.) and seems suited to the manufacture of face brick or conduits.

From these various tests it is evident that fire clays ranging from good flint clay to lower grade plastic clays accompany the Allegheny coals. Such clays could be used for fire brick or buff face brick. With them are brownish shales which also could be used in brick making. The greatest drawback to the development of the clays is their high elevation above railroads or main highways. For the better grades of fire clay, however, such transportation difficulties could be solved.

The areas in which the Allegheny clays and shales are to be expected are in the belt crossing the county from southwest to northeast between Emporium and Cameron, particularly at the head waters of Sterling Run. In the hills in the northwestern part of the county are large areas of Allegheny strata and extension of the Norwich coal basin of McKean County. Nothing is known of the clays of that area.

Physical tests of Cameron County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point cone	Best burning range—cones	Firing color	Suggested uses
242	20.6	1.7	1	—	5.8	9	31	07-9	Light cream	Fire brick
243	20.2	2.5	2	85	6.6	6	27	07-4	Cream to gray	Fire brick, face brick
246	—	—	—	—	3.6	02	20	07-4	Cream to gray	Face brick, conduits

No chemical analyses were made.

- 242. Flint clay on Sterling Run.
- 243. Plastic clay near Calder
- 246. Sandy clay north of Beechwood.

References to the geology of Cameron County:

- Ashburner, C. A., The township geology of Cameron, Elk, and Forest Counties: Pennsylvania Second Geol. Survey, vol. R2, pt. 11, 1885. (The portion on Cameron County by A. W. Shaefer.)
- Ashburner, C. A., Atlas for Cameron, Elk and Forest Counties: Pennsylvania Second Geol. Survey, R2 Atlas, 1884.

CARBON COUNTY

Carbon County lies between Monroe and Schuylkill Counties in eastern Pennsylvania. It lies within the Ridge and Valley section with the exception of the northeastern part which is on the Pocono Plateau of the Appalachian Plateaus province.

The Lehigh River borders the county on the northeast and then cuts south across the county through Mauch Chunk and out through Lehigh Gap in Kittatinny Mountain, which forms the south border.

The sedimentary rocks throughout the county are of Silurian, Devonian, Mississippian, and Pennsylvanian age. The sequence and approximate thickness is as follows:

	Feet
Pennsylvanian	
Coal Measures	975
Pottsville sandstone	1,000
Mississippian	
Mauch Chunk red shale	2,168
Pocono sandstone	1,253
Devonian	
Catskill red beds	7,145
Middle Devonian shales and sandstones	3,500
Onondaga limestone and Oriskany sandstone	600
Silurian	
Bloomsburg red shales	2,000
Clinton and Tuscarora sandstones	1,000

The upturned Clinton and Tuscarora sandstones form the sharp ridge, Kittatinny Mountain, along the southern border of the county. At the northern base of this mountain, the Bloomsburg division of the Silurian forms a narrow belt of upturned red and green shales. These shales are of good quality and suitable for brick making. They are crossed by the Lehigh River at Palmerton and their outcrop extends east and west of the river in a narrow belt.

The Onondaga and Oriskany formations cross the county in a narrow belt and to the north are succeeded by a broad belt of Middle Devonian sandstones and shales which underlie much of the county south of a northeast-southwest line drawn through Packerton. Leighton and Weissport lie within this belt on the Lehigh River. Within the Middle Devonian are many gray shales suitable for brick making, although some are too carbonaceous and some too siliceous.

The red shales and sandstones of the Catskill series appear along Lehigh River at Packerton. They form a narrow belt west of the river but east of the river they spread north over the northeast part of the county, a part of the Pocono Plateau. The strata are here

nearly horizontal and, according to Willard, are the Mount Pleasant shales of Catskill age. Willard restricts the Pocono to a belt near the Lehigh River. In the Mount Pleasant division there are many soft red shales which might be used.

West of the Lehigh River and southwest from Mauch Chunk lies the eastern end of the Southern Anthracite Field or Pottsville coal basin. It is rimmed on the south by Pocono sandstone in Mauch Chunk Mountain and on the north by a wider area of Pocono sandstone, Broad Mountain. Within these ridges lies a lowland of Mauch Chunk red shales which underlie the borough of Mauch Chunk and can be seen in many of its cliffs. The softer beds of this shale are suitable for brick making. Within the belt of Mauch Chunk shales the Pottsville sandstones rise as a subordinate ridge west of Mauch Chunk and open out west so as to enclose a basin of dark slates and anthracite beds. The shales are too dark or too slaty to be of much value in brick making.

North of the Pocono area of Broad Mountain is another synclinal coal basin, a part of the Middle Anthracite Field. The Pottsville sandstone and irregular synclinal areas of coal and shale make up the northern border of the county west of the Lehigh River. Between Broad Mountain and the Pottsville sandstones is a wide belt of Mauch Chunk shales which cross the Lehigh River in certain areas. Here again is an opportunity for their use in brick making.

There are now no brickyards in the county. The Bloomsburg red beds in the south, and the Mauch Chunk red beds at Mauch Chunk and in the northwestern area seem the most promising sources of materials.

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CENTRE COUNTY

Its name describes the location of Centre County but not its irregular shape. The county is 66 miles in longest dimension and includes the Ridge and Valley section, the Allegheny Front, and high plateau. Bedrock ranges in age from Gatesburg of Upper Cambrian to Conemaugh of the Coal Measures.

The portion of Centre County that is underlain by strata of the Pennsylvanian period and therefore carries coal and fire clay beds is coextensive with the Allegheny Plateau area. The southeastern edge of this physiographic feature, the Allegheny Front or Allegheny Mountain, extends southwest across the country from Monument on Beech Creek to the southwest corner of the county, south of Sandy Ridge. Northwest of this line lies the plateau portion of the county. At the plateau edge elevations rise to 2,200 feet above sea level. To the northwest the plateau slopes downward into a lower area of coal basins, the Beech Creek, Snow Shoe, Philipsburg, and Osceola basins whose higher hills rise to about 1,400 to 1,600 feet above the sea. Northwest of this basin area the plateau again rises to heights of over 2,000 feet in a wild mountainous belt along the Laurel Hill-Pine Glen-Hyner antiline. Northwest of this tract the surface again slopes down into the Karthaus-Renovo syncline along the Susquehanna River. The plateau is breched by Beech Creek on the east; Moshannon Creek on the west, and by the West Branch of the Susquehanna River on the northwest. Branches of the Pennsylvania Railroad ascend the Front from Bald Eagle Valley, the Tyrone-Clearfield branch through Sandy Ridge and the Snow Shoe branch to Snow Shoe. The New York Central Railroad follows Beech Creek into the Snowshoe basin and follows the Susquehanna River into the Keating and Karthaus areas.

Most of the plateau in the county is underlain by Pottsville sandstones and conglomerates and is wild and wooded. The underlying Mauch Chunk and Pocono beds of the Mississippian are exposed along the valleys of Beech Creek in the Orviston area, along the Susquehanna River from Karthaus to Keating and up the southern tributaries and in small areas south of Sandy Ridge. The Allegheny group is exposed in the Beech Creek, Snow Shoe and Philipsburg basins (the "First Basin") and in scattered areas in the second basin along the highlands of the Susquehanna River, especially near Karthaus. The important coal mining areas are in the Philipsburg and the Snow Shoe basins. In the southwestern part of the county, west of the Tyrone-Clearfield branch of the Pennsylvania Railroad and southwest of Sandy Ridge, the surface rocks are chiefly Pottsville sandstones with remnants of the Allegheny group on the higher lands.

This is for the most part a wooded, unexplored area in which no clays are worked but in which clays may be uncovered in the lower Allegheny and upper Pottsville beds. It lies between the important fire clay mining area at Blandsburg and Dean in Cambria County and the old clay area at Sandy Ridge and Powelton.

Southwest corner of county

Along the Clearfield branch of the Pennsylvania Railroad, important clays have been worked. At Sandy Ridge, just east of the village, flint and soft clay was formerly mined on a large scale and fire brick manufactured. The general section showed about 5 to 10 feet of dark shale carrying a thin coal, underlain by 2 to 5 feet of soft, blue fire clay and this in turn underlain by from 2 to 3½ feet of flint clay with 2 to 4 feet of soft clay below the flint. The whole section is below the Brookville and is taken to represent the Mercer horizon. In early days, the soft clay alone was used but the greater value of the hard clay was discovered and it became the chief clay used in the manufacture of no. 1 fire brick. The upper soft clay was used in making furnace bottoms and the lower soft clay for tiles and in walls of furnaces. By 1884 the production amounted to 60 tons a day. Sandstone under the clay was crushed and used as a grog in brick making. Analyses made of these clays in 1870 are given in vol. T 4 of the Second Pennsylvania Geological Survey and additional notes in vol. H of the same Survey.

About three-quarters of a mile north from these workings were the Powelton clay mines. These were owned in 1884 by R. H. Powell & Company and leased to James Pierpoint and Frank Wilcox. The clay was of the same bed as that at Sandy Ridge and of about the same section. In 1884 they were producing about 100 tons of clay a day. The clay was trammed to Powelton and about 12,000 fire brick were made daily. After a long period of production these clays at Sandy Ridge and Powelton were exhausted and at present (1940) are not worked. The Harbison-Walker Refractories Company has a fire brick plant at Retort and the General Refractories Company has a plant at Sandy Ridge. At present (1940) only the Harbison-Walker plant is in operation. It uses plastic clay from Wallaceeton and flint clay from the head of Morgan Run near Burly in Clearfield County.

The clay below the Brookville coal near Retort is soft and varies from 3 to 5 feet thick. A sample of this clay (no. 275) from the Twigg mine shows fairly good plasticity. It fires cream to gray with a firing range from cone 01 to 13 and fuses at cone 31. It seems to be an excellent clay for fire brick manufacture.

Moshannon Creek

Bordering Moshannon Creek on the east through Osceola, Philipsburg and north to Coaldale there is a belt or basin of Allegheny strata

with an average width of two miles, the Centre County portion of the Philipsburg coal basin. The Brookville and the Lower Kittanning coals are the chief coals mined and they are accompanied by plastic underclays. The clay from the Twigg mine two miles west of Retort represents one of these and a second sample was collected from the Schnar mine between North Run and Barlow Hollow, 3 miles north-east of Philipsburg. This clay lies beneath the Brookville coal and is 12 feet thick. The upper two feet are flint clay and the lower 10 are plastic clay. No. 67 represents the average of the entire bed. According to Shaw, who describes this clay in Bulletin M 10, this is a fairly good no. 3 fire clay overfiring at cone 12 and fusing at cone 20. Plastic clays at these horizons and many good brown brick shales are to be expected in the Philipsburg basin.

From Philipsburg to Peale the Moshannon flows in Pottsville and Pocono strata and with the exception of the Philipsburg coal basin just mentioned the entire plateau thence south to the crest of the escarpment is a wooded area of the same rocks. This area is traversed by Black Moshannon Creek and Sixmile Run. Flint clays are to be expected in the Mercer horizon over this plateau but none are now mined. Formerly the General Refractories Company operated the Forge Run mine seven miles east of Philipsburg (Buck Creek Clay Mine on topographic map) at the head of Sixmile Run. A long tram road extended down Sixmile Run connecting the mine with the New York Central Railroad. The rails have been removed and the mine was abandoned, but was operated in a small way in 1940. The clay (no. 55), according to Shaw in Bulletin M 10, is a good no. 2 fire clay fusing at cone 30½.

Between Viaduct and Peale on the east side of the Moshannon the General Refractories Company has long operated a clay mine known as the Peale No. 1 mine. The clay lies below the horizon of the Lower Kittanning and the Brookville coals and is probably a Mercer clay. The section shown near the mine is as follows:

	Feet
Shale and clay	10
Sandstone, sometimes absent	3
Clay and dark shale	12
Coal	1
Soft gray clay	2
Dark semi-hard clay	2½
Sandstone	8

The upper half of the 12-foot bed is mined and it usually consists of 4 feet of flint clay underlain by 2 feet of softer clay. The upper clay (no. 56) has excellent burning properties and fuses at cone 32. It is a no. 1 flint clay. No. 57, the lower portion, is a smooth plastic clay which begins to overfire at cone 15 and fuses at cone 32. It is also a no. 1 clay. The clay is shipped by way of the New York Central

Railroad to the plants of the company. On the higher hills to the east the Lower Kittanning and Brookville coals have been mined but their clays have not been developed.

Northeast from the Black Moshannon the Pottsville strata continue along the edge of the escarpment to the Orviston district. No clays have been developed but with good Mercer clays mined at Monument a few miles to the northeast it would seem that flint and plastic clay might be found in the high hills to the west and southwest of Orviston. The fire brick plant of the Centre Brick and Clay Company at Orviston has been dismantled. The plant of the General Refractories Company uses clay from Clearfield County and from Peale for machine- and hand-made fire brick.

North of Snow Shoe

From Moshannon northeast through Snow Shoe and Clarence to the Clinton County line is a belt of Allegheny strata known as the Snow Shoe coal basin. These beds made a belt from 3 to 4 miles wide. The entire section of about 250 feet of Allegheny strata is exposed within the basin but coal mining is confined chiefly to the Lower Kittanning and the Brookville beds. Both of these, and some of the upper beds, carry plastic underclays, but little has been used. The James H. France Refractories Company operates a large fire brick plant at Snow Shoe on the New York Central Railroad, using flint clay from what is probably the Mercer bed.

Two underground mines and a steam-shovel stripping 2 to 3 miles north of the plant furnish the clay, which is delivered by rail. Machine- and hand-molded fire brick and shapes are burned in 12-round periodic down-draft kilns of 50,000 capacity each. This company also operates a fire-brick plant in the hairpin loop of Moshannon Creek just east of Winburne.

Northwest from the Snow Shoe basin is a high area of Pottsville rocks with elevations of 2,000 feet or more. No clays are known in this area although the Mercer horizon near the top of the Pottsville may yield good clay. Northwest from this mountain is the deep valley of the Susquehanna River. The river and its main tributaries cut deeply into Pottsville, Mauch Chunk, and Pocono strata. No clays are to be found along it except perhaps red clays of the Mauch Chunk series. These should be available east of Peale and east of Karthaus. The high hills in the vicinity of Karthaus carry remnants of the Lower Allegheny strata; soft clays similar to those once mined in Clearfield County near Karthaus might be utilized.

Bald Eagle Valley

The eastern edge of the Allegheny plateau capped by the Pocono sandstones is known as the Allegheny Mountain or Allegheny Front.

From its edge steep slopes carry the surface down through outcrops of Catskill red beds and Middle Devonian shales to the Bald Eagle Valley, a main highway from Blanchard to Hannah Furnace. Many short tributaries of Bald Eagle Creek head in the Allegheny Front and cross the belts of Catskill and lower shales. Among these strata are many shales suitable for brick manufacture, especially in the Catskill red series. The valley bottom itself, which the Pennsylvania Railroad and the highway follow, is mostly upon Marcellus shale not of high quality for brick making.

The section below the Pocono sandstone rim rock is as follows:

	Feet
Catskill formation	1,600
Chemung formation	2,800
Brallier shale (upper Portage)	1,500
Harrell shale (lower Portage)	300
Burket black shale	50
Hamilton formation	600
Marcellus shale	100

A brick plant at Central City (Milesburg) uses the Brallier shale from a pit three-quarters of a mile up Moose Run from Central City. The shale is mixed with alluvial clay from a fan at the mouth of Moose Run, the clay being weathered material brought down by Moose Run from the shales traversed. The brick yard makes red brick and hollow tile.

East of Bald Eagle Creek rises Bald Eagle Mountain and on its flank there should be Clinton shales which at Castanea (Clinton County) have been used in face brick manufacture. Bald Eagle Mountain is the west limb of a huge anticlinal fold of Tuscarora (Lower Silurian) sandstone which appears again in Nittany, Brush, Tussey, and the Seven Mountains in the eastern part of the county. These are sandstone crests and present little of interest to the clay-worker though they furnish much pure sandstone as ganister and for silica brick manufacture.

Nittany Valley

Between Bald Eagle Mountain and the eastern ridges lies the great Nittany Valley of Ordovician and Upper Cambrian limestones, with its extensions, such as Brush Valley. On the flanks of the surrounding mountains lie the Upper Ordovician shales which are usually too slaty to use in brick making. In the limestone valleys deep weathering has produced a heavy bed of residual clay ranging from a few to over 100 feet thick. This varies in character with the type of underlying rock, some resting on pure limestone, some on argillaceous sandstones and some on shaly limestones. The best quality of clay seems to rest on the dolomite and quartzite of the Gatesburg formation of the Upper Cambrian age.

There are many highly colored plastic clays which could be used in the making of brick, drain tile or some types of stoneware, but the clay most sought for is a white residual clay, white in the raw state and burning white. This type is a kaolin carrying much siliceous material so finely divided that it is usually impossible to get a true kaolin or china clay by washing. The clay is therefore used chiefly by the steel companies as a cement between fire brick. Attempts to use it in china or paper manufacture have not proven successful. Many prospects have been opened on pockets of white clay in Centre County, a few of which are described.

Scotia. These clays lie in a wooded area of Gatesburg sandstone between Scotia and Stormstown in Centre County, west of State College. The property can be reached by a road from Buffalo Run. It is owned by R. R. Blair of State College. Samples of the clay are said to have been successfully washed with Dorr classifiers and a product acceptable to various industries has been produced. The property was worked in early days for iron ore and white clay was encountered in the pits. Between 1915 and 1918 considerable prospecting was carried on in pits and shafts. It is reported that at one point 21 feet of white clay and at another opening 14 feet of cream-colored material was exposed. No development has been done in recent years and the old exposures are obscured. Tests made by Ries¹ on these clays show that at 1150°C (cone 1) one sample showed 16.2 percent absorption and another 29 percent. The product was a cream color and not steel hard. At 1350°C (cone 11) the first sample showed 15.7 percent absorption and at 1300°C the other sample showed 19.1 percent absorption. Ries states that after washing, the clay would probably be suited for use in white ware and paper manufacture. Another sample according to Moore² showed at 1150°C (cone 1) a porosity of 46.6 percent, was almost steel hard and had a white color. At 1350°C (cone 11) its porosity was 36.4 percent, it was steel hard, and had a cream white color.

Furnace Road. This pit has been known as the Kelsey ore pit, the Gates mine, and the Colonial Clay Company mine. It was or is now controlled by the Everett-Saxton Company, 1710 Franklin Trust Building, Philadelphia, Pennsylvania. It is located one mile north of Furnace Road Station on the Scotia-Tyrone branch of the Pennsylvania Railroad in Centre County. In former years white clay has been excavated from large pits with steam shovels and drag line and hauled to Furnace Run for shipment. In 1927 the railroad discontinued service and no further mining was done. The Bellefonte Cen-

¹ Ries, H., High-grade clays of the Eastern United States: U. S. Geol. Survey Bulletin 708, p. 94, 1922.

² Moore, E. S., White clay deposits in Central Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull 45, p. 3, 1922.

tral Railroad now controls the branch railroad. Prospecting in the east end of the pits and drillings show six feet of plastic white clay above water level and 16 feet below. The old pits are now filled with water. They were last worked under lease by E. Ellenberger of Pennsylvania Furnace in a pit 75 by 400 feet. Pockets of good clay from 5 to 20 feet thick were worked. The white clay grades irregularly into white sand or into yellowish and pinkish varieties of clay. Tests by Ries¹ show at 1150°C (cone 1) an absorption of 28.9 percent, a hardness not steel hard and a white color. At 1300°C (cone 9) the absorption was 24.8 percent and the product was steel hard and had a faint cream-white color. In 1922 four to seven cars of clay were shipped weekly, its use being chiefly for saggars and as a cement in Bessemer converter linings, hot metal ladles and cupolas.

Struble. At Struble, south of State College, red brick suitable for "back-up" work have been made from mixed color, plastic clays accumulated from an abandoned iron ore washing plant. These are residual clays derived from the Nittany dolomite.

Localities from which Centre County samples were obtained:

- 55. Semi-flint clay. Forge Run mine, 7 miles east of Philipsburg.
 - 56. Flint clay. Peale No. 1 mine, 1 mile north of Viaduct, upper clay.
 - 57. Plastic clay. Peale No. 1 mine, 1 mile north of Viaduct, lower clay.
 - 67. Plastic clay, Brookville bed. Schnar mine near Ophir.
- Samples 55, 56, 57, 67 described by Shaw in Bull. M 10, Pennsylvania Geological Survey, 1928.
- 275. Plastic clay, Brookville bed. Twigg mine, 2 miles west of Retort.

Nine analyses of the clays from Sandy Ridge and Powelton are recorded in Rept. T 4, of the Second Geological Survey of Pennsylvania, pp. 117-120, 1884. They are as follows:

- A 1 Sandy Ridge upper blue soft clay.
- A 2 Sandy Ridge hard clay, second layer.
- A 3 Sandy Ridge under strata, soft clay, third layer.
- A 4 Sandy Ridge bottom layer, sandy clay floor.
- A 5 Sandy Ridge average clay.
- A 6 Powelton hard clay.
- A 7 Powelton under strata.
- A 8 Powelton soft blue clay.
- A 9 Powelton sandy bottom.

¹ Ries, H., loc. cit. p. 96.

Physical tests of Centre County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point (cone)	Best burning range (cones)	Firing color	Suggested uses
55	21.43	8.93*	3		23.05*	6	30½			No. 2 fire clay
56	23.06	15.32*	2½		24.25*	14	32			No. 1 fire clay
57	25.95	11.58*	5		27.45*	11	32			No. 1 fire clay
67	27.98	17.70*	4		28.54*	9	20			No. 3 fire clay
275	19.4	3.3	4	60	5.10	4	31	02-11	Cream to gray	Fire brick

* Volume shrinkage.

Chemical analyses of Centre clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO	P ₂ O ₅	SO ₃
67	8.00	53.89	2.27	.60	30.49	1.96	1.09	1.03	.60	.02	.86	.03
A1	9.65	45.65	3.54		34.73	.11	.61	5.75				
A2	13.05	44.95	2.70		37.75	.30	.21	.98				
A3	10.13	45.82	3.33		35.95	.11	.57	4.13				
A4	4.88	74.95	1.89		15.94	.10	.40	1.75				
A5	10.37	45.88	4.68		33.92	.16	.75	4.64				
A6	13.74	42.32	.95	3.83	37.01	.47	.16	1.29				
A7	11.39	45.72	1.34		39.14	tr.	tr.	2.05				
A8	11.52	48.87	2.93		34.43			1.96				
A9	8.02	60.80	1.34		28.15	tr.		1.48				

Selected references to the geology of Centre County:

Butts, C. (and Moore, E. S.), *Geology and Mineral Resources of the Bellefonte Quadrangle, Pennsylvania*: U. S. Geological Survey, Bull. 855, 1936.

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Moore, E. S., *White clay deposits in central Pennsylvania*: Pennsylvania Topog. and Geol. Survey, Bull. 45, p. 2, 1922.

Platt, F., *First report on Clearfield and Jefferson Counties*: Pennsylvania Second Geol. Survey, vol. H, 1875 (p. 119 et seq. gives information regarding the Sandy Ridge fire clays).

Shaw, J. B., *Fire clays of Pennsylvania*: Pennsylvania Topog. and Geol. Survey, Bull. M 10, 1928.

Sisler, J. D., *Bituminous coal fields of Pennsylvania, Pt. II*: Pennsylvania Topog. and Geol. Survey, Bull. M. 6, pt. II, 1926 (pages 128-134 describe the coals of Centre County).

CHESTER COUNTY

Chester County lies east of Lancaster County. Its southern boundary is Delaware and Maryland. In general it is an area of low, rolling topography and lies within the Piedmont topographic province. The northeastern portion along the Schuylkill River is a part of the Triassic Lowlands. Pre-Cambrian crystalline rocks underlie much of the county, interrupted by sharp ridges of Cambrian quartzites, such as Welsh Mountain, Thomas Hill, Barren Hills, and North Valley Hills. The upland is broken by a narrow valley of Cambrian and Ordovician limestones which crosses the middle of the county from east to west through Downingtown, Coatesville, Parkesburg, and Atglen.

Triassic lowlands. Ten thousand feet of Triassic shales and sandstones dipping northwest underlie a belt 5 to 8 miles wide along the northeastern border of the county south from the Schuylkill River. They have been intruded by many dikes and sills of the igneous rock, diabase, and near these intrusions the shales have been baked and hardened. Three formations are recognized, the Stockton, Lockatong, and Brunswick, the latter the youngest. These crop out in three bands across the northeastern border of the county, the Brunswick nearest the Schuylkill River. The Stockton and Lockatong formations are chiefly sandstones with but few good shale beds. The Brunswick is more largely made up of soft red shales with some greenish or gray shales. West from the Schuylkill River, the formation becomes more sandy and in the western portion very conglomeratic. There are, therefore, not many exposures of Triassic shale suitable for brick making and none is now utilized. A few years ago the Spring City Brick Company, half a mile south of Spring City along the Schuylkill River, made red brick from a siliceous weathered red shale from the Brunswick formation. Just to the north of Chester County and east of Pottstown a small brick yard, the Joseph S. Garber Brick Company, many years ago made red brick from the Brunswick shales.

At present (1940) the only brickyard in the county using Triassic shale is that of the McAvoy Vitrified Brick Company. Their plant and pits are in the loop of the Schuylkill River east of Phoenixville and west of Oaks between the Reading Railroad and the river. The material used is red and blue shale of the Stockton formation, much of it weathered to red and yellow clay. These clays and shales have been worked since 1895. Originally, the products made were vitrified sewer pipe and paving brick. Besides these they now make building brick, drain tile, and hollow tile.

This plant and several plants in Montgomery County prove that the softer, weathered Triassic shales are of value in the manufacture of various clay products.

Honeybrook upland. South from the Triassic belt and north of Chester Valley is a rolling upland underlain by a complex of pre-Cambrian igneous and metamorphic rocks with smaller areas of Cambrian quartzites all compressed into a series of northeast-southwest folds. The most resistant rock of the area is the Chickies quartzite of Lower Cambrian age. It forms pronounced ridges such as Welsh Mountain. This quartzite is several hundred feet thick and is overlain in succession by the Harpers phyllite, 600 feet, and the Antietam quartzite, 300 feet. The whole series makes up the higher hills of the county.

The Chickies quartzite is in part resistant pure quartzite and in part more sericitic quartz schists. It generally is feldspathic and the schistose portions have been reduced to siliceous kaolins or to kaolinitic sands. These residual white clays have been worked extensively near Narvon, Lancaster County, along Welsh Mountain (see Lancaster County.) They are used in steel mill furnace cements, linoleum manufacture, and paper filling, but are not pure enough for the manufacture of china. The continuation of Welsh Mountain along the northwest border of Chester County and the northeast extensions, such as Thomas Hill, should contain similar kaolins. Similar conditions prevail in the Barren Hills south of Honeybrook and in narrow ridges of Chickies quartzites on the north rim of Chester Valley. In these areas in Chester County much kaolinitic sand has been dug but none of it rich enough in clay to be used as white clay. Pockets of richer clay content may yet be found with the Chickies quartzites in the county, or methods of washing the kaolinitic sands may be improved.

The pre-Cambrian uplands north of Chester Valley are chiefly underlain by gneisses, granodiorite, anorthosite, gabbro, and serpentine. When deeply weathered these should yield residual clays. Usually, however, these uplands have only a thin cover of stony residual soil of no ceramic value. Only one occurrence of kaolin has been noted within the area. Kaolin was produced from 1880 to 1912 on the Israel A. Berry land half a mile northwest of Cedar Knoll in West Caln Township. This is apparently a residual clay derived from granodiorite which underlies a large part of the uplands.

Chester Valley. A long narrow syncline enclosing Cambrian and Ordovician limestones crosses the middle of the county. This is the Chester Valley. It is one to two miles wide, is underlain by Cambrian and Ordovician limestones and rimmed to the north and south by

pre-Cambrian igneous and metamorphic rocks. Within the valley are concentrated important cities such as Coatesville and Downingtown, important railroads and highways, and excellent farm lands. The limestones of the valley bottom are capped by yellow plastic residual clays which could be used in brick and tile manufacture, and on the north side of the valley there may be kaolinitic sands derived from the Cambrian quartzites of the north rim or from the Kinzers formation. Kaolin was obtained $1\frac{1}{2}$ miles northeast of Coatesville as a washed by-product from a kaolinitic sand some years ago (1932). The sand was removed in gravity troughs and the pure clay was pressed and shipped to Hockessin, Delaware, where it was further refined and mixed with other clays.

South Valley Hills. South of the Chester Valley the Piedmont upland continues to the southern border of the county as a rolling area of complexly folded igneous and metamorphic rocks, chiefly schists, with smaller areas of gneiss, quartzite, and marble. Whether all of these are pre-Cambrian or whether the schists in the South Valley Hills are Upper Ordovician in age is still a disputed question.

Small areas of colored residual clays are to be expected over most of the area and kaolinitic sands as residual around the more quartzitic formations, such as the Setters formation. Between Avondale and Toughkenamon pits 70 feet deep have been dug in a kaolin found 6 feet below the surface. This clay was washed and shipped to Trenton and East Liverpool.¹ It is evidently residual from a pegmatite dike as there are many such dikes near Avondale. Residual clays from pegmatite dikes have in the past yielded much good kaolin. The chief production has come from deposits at Kaolin in Chester County and was sent to Hockessin, Delaware, two miles to the southeast, for refining. The schists here are intruded by northeast-southwest dikes of pegmatite from which both kaolin and feldspar have been obtained. Kaolin mining was begun at Kaolin in 1839 and was continued for many years. All the mines are idle. The washed clay was shipped to East Liverpool, Ohio and Trenton, N. J., and to Canada. Near Hockessin, kaolin averaged 60 feet in depth and was worked to 120 feet in depth.

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CLARION COUNTY

Clarion County lies east of Butler and Venango Counties and north of Armstrong County. It is bounded on the south by Redbank Creek and on the southwest by Allegheny River. The topography of the county is that of a high rolling upland cut by deep, winding rivers. The southern half is given over to agriculture and to coal mining; the northern portion is largely forested. Redbank Creek drains the southern townships. Clarion River flowing across the middle of the county in a deep winding course drains the upper two thirds of the county. Its main southern tributaries are the Licking, Piney, and Mill Creeks; its northern tributaries are Turkey Run and Beaver, Canoe, Deer, and Toby Creeks.

The exposed strata of the county include a section from the lower Conemaugh group, through the Allegheny group and Pottsville series, and down into the underlying Mississippian beds. These rocks are but slightly folded and in general appear to be horizontal. Only the lower 200 feet of the Conemaugh group is seen in the county and that only in some of the higher hills near the southern border. Good brick shales are expected in the Conemaugh but its position makes it not very accessible. The Allegheny group averages about 300 feet thick. It forms the surface over the greater part of the county. Lines¹ gives the following rough section of the strata, emphasizing the possible clay horizons:

Coal (Upper Freeport)	Coal	Shale and sandstone
Plastic clay	Plastic clay	Limestone
Limestone	Shale and sandstone	Sandstone
Flint clay	Coal (Middle Kittanning)	Shale
Shale and sandstone	Plastic clay	Coal (Upper Clarion)
Coal (Lower Freeport)	Shale	Plastic clay and shale
Plastic clay	Coal (Lower Kittanning)	Coal (Lower Clarion)
Limestone	Plastic clay	Plastic clay
Shale and sandstone	Coal (Lower Kittanning?)	Shale
Coal (Upper Kittanning)	Coal (Lower Kittanning?)	Coal (Brookville)
Plastic clay	Flint and plastic clay	Clay
Shale and sandstone		

N. B.—If these three columns were in one, Upper Freeport coal would be at the top and Brookville coal at the bottom.

There is still some confusion regarding the exact correlation of the lower coals in the Allegheny group in the county and the boundary between the Allegheny and Pottsville groups is therefore in dispute. Sisler² says "Work during 1921 demonstrated what has long been suspected that the Craigs ville coal of the Foxburg-Clarion folio is the equivalent of the Brookville coal of Brookville and that coals

¹ Lines, E. F., *Clays and shales of Clarion Quadrangle, Clarion County, Pa.*: U. S. Geol. Surv. Bull. 315, p. 336, 1907.

² Sisler, J. D., *op. cit.*, p. 141, 1926.

mapped locally as Brookville are at the Mercer horizon. Due to this error confusion will exist in this area until the county is re-surveyed."

The Lower Kittanning is the most important coal of the group, the Lower Clarion and the Upper Freeport ranking respectively second and third. The lower Kittanning flint and plastic clays and the Clarion clays are the most important clays of the group.

The Pottsville series comprises about 40 feet of coarse sandstone, the Homewood, at the top, underlain by from a few to 40 feet of Mercer shales, coals, and clays, including good flint clay, and under these is from 30 to 50 feet of sugary sandstone, the Connoquenessing. Pottsville beds are exposed along Redbank Creek except in the New Bethlehem-Hawthorn section; along Allegheny River; along Clarion River and practically all of its tributaries in the county; and in the high plateau region of the northeastern townships. The valuable flint clay to be found near the top of the Pottsville group in the Mercer horizon makes it of special interest to the clay-worker.

Below the Pottsville beds, in the absence of the Mauch Chunk series, the sandstones of the Mississippian appear, the chief sandstone being known as the Burgoon. These are exposed along Clarion River for its entire course across the county and along Redbank Creek west of Climax. They may carry brick shales but for the most part they are far too sandy to be of value.

North of the Clarion River.—This region is served by the Baltimore & Ohio Railroad which crosses it from the Allegheny River and St. Petersburg, passing northeast through Edenburg, Shippenville, Clarion Junction, Lucinda, Leeper and on to the north; and by the New York Central Railroad which comes into the county from Franklin, passes through Elmo and Shippenville and thence south across the Clarion River and up Piney Creek. Good roads, many of them of concrete, make shipping by truck easy.

The extreme northern townships are underlain chiefly by Pottsville sandstones and are heavily wooded. They probably carry no clays of importance. The area northwest and north of Clarion, from Clarion Junction north to Lucinda and Huefner, has been an active producer of flint clay for many years. The Baltimore & Ohio Railroad through Arthurs and Lucinda passes over an area of lower Allegheny strata and the Lower Clarion coal is mined. West of the railroad in Paint Creek valley the Pottsville rocks appear and flint clay is found in the Mercer horizon. Several companies have operated here in the past, including the Niles Fire Brick Co. The mine of this company was in the Paint Creek valley about two miles east of Shippenville. The mine was connected by a tram road with a loading tipple near Arthurs station. The clay was shipped out of the district to the company's plant at Niles, Ohio. Operations have ceased and

equipment has been removed. The flint clay ranges from 2 to 8 feet in thickness and is roofed and floored with heavy sandstone. The clay (no. 380) is a true flint clay with poor plasticity and low green strength. It fires white to gray with a firing range from cone 01 to 13. It fuses at cone 33-34 and is well suited to the manufacture of high grade refractories. The abandonment of some of the other properties was due to excessive iron in some of the clay but it is likely that under a forest cover good clays are still to be found.

The Niles Fire Clay Company in 1940 is mining hard flint clay one mile south of Lucinda from a bed that ranges in thickness from 1 to 12 feet. The clay is shipped by rail to the company's plant at Niles, Ohio, as is plastic clay mined at Hillsville, Lawrence County.

J. F. Eiswerth of Lucinda is mining fire clay one mile south of Lucinda and half a mile west of Route 68. He delivers the clay by truck to the McLain Fire Brick Co. at St. Charles in the south end of the county.

W. D. Little of Philipsburg mined flint clay in 1940 about 1½ miles southeast of Marble (2 miles by road), on the west side of Mahles Run.

Flint clay also occurs below the Lower Kittanning coal in the region just north of the river but in general it is not so pure as that on the south side of the river.¹ At Clarion Junction and in an area extending two miles southwest and south from the junction many outcrops of this clay occur and considerable clay has been taken out in past years, much of it by stripping methods. Lines¹ gives the following notes on localities:

Clarion Junction, one-half acre stripping on each side of the pike.

Clarion Junction, southeast of, on F. M. Shannon farm (reported).

Clarion Junction, 1½ miles southwest of; open pit on portion of John Rapp farm, now owned by the Niles Fire Brick Co. There is a 3-foot exposure of clay here and an examination of the face showed that much of the clay had inclusions of impurities.

Clarion Junction, 2½ miles south of, on Wagner and Bell farm; old stripping uncovering about one acre. No clay was exposed here but the clay formerly mined was reported to be of fair quality.

Clarion Junction, 1 mile west of, on road running south to Piney. It is roughly estimated that between 10 and 15 acres in this vicinity are underlain by clay within 8 to 10 feet of the surface.

Shippenville, 3 miles south of, on road to Piney, near top of rise; bed under light cover.

The northwestern townships are underlain by the Allegheny group and some mining is done in the Lower Clarion and the Lower Kittanning coals. No flint clays are recorded in this area but plastic clays are to be expected under the coals. The main valleys of the Allegheny and the Clarion are cut far below the Allegheny group and in them little in the way of useful clays may be expected.

¹ Lines, loc. cit., p. 340.

South of the Clarion River.—With the exception of the deeper valleys the surface rocks of the region are of the Allegheny group. Brown shales suitable for brick making are common. Plastic clays are found under most of the coals but the Lower Clarion and the Lower Kittanning clays seem best and are most persistent. West of Corsica on the Clarion-Jefferson County line, the De Haven Coal Co. in stripping the Lower Kittanning coal removed 15 or more feet of shale tested as no. 295. This shale has a fairly good plasticity and a fair green strength. It fires red with a firing range from cone 08 to cone 04. It seems suited to the manufacture of face brick. Prospect pits have been dug below the coal into the underlay. This clay is at least 6 feet thick, the lower portion sandy. No. 296 represents the upper three feet of better material. This has a fairly good plasticity and a fair green strength. It fires to a light to dark gray color with a firing range from cone 06 to cone 13. It fuses at cone 32. It is classed as a high grade plastic fire clay suitable for the manufacture of fire brick and other refractories. This shale and clay are well located and in various mixtures many products might be made.

The Lower Kittanning clay is also exposed at the brick plant two miles southeast of Clarion. This plant, known as the Clarion Brick Co. of Clarion, and closed several years prior to 1940, was formerly operated as the Clarion Refractories Co. and as the Haws Clay Products Co. Fire brick, paving brick, and face brick have all been made at the plant. The section shows:

Feet	
—	Lower Kittanning coal
6	soft clay
20	concealed
5	flinty clay or shale
4-9	flint clay.

No. 378 represents the flinty clay or shale from the bins of the plant. It has good plasticity and a low green strength. It fires white to dark gray and has a burning range from cone 6 to cone 12. It fuses at cone 19. It is not a fire clay but is suitable for the manufacture of face brick, sewer pipe, or tile.

South from this locality on Route 66 many outcrops of the Lower Kittanning clay are to be seen. Sample 379 represents this clay as exposed on the road 1½ miles north of Spaces Corners. Under a one-foot coal bed, 4 feet of light clay and 3½ feet of dark clay are seen. The sample is the average of all the clay. Its plasticity is very good and green strength low. It fires to a cream buff to gray with a burning range from cone 3 to cone 12. It fuses at cone 28. It is suited to face brick manufacture and might be used as a bond clay

in certain refractories. Plastic clay under this coal seems persistent over much of the area. Lines¹ notes it at the following localities:

A. V. Confer coal bank, just east of Strattonville; 3 feet, apparently of good quality.

Coal bank on Lewis Deitz farm, $3\frac{1}{2}$ miles northeast of Sligo; two feet, of excellent appearance.

J. K. Andrews coal bank, on Jas. Myers farm, 3 miles northeast of Sligo; 3 feet 10 inches.

Country bank on Chas. McCall farm, $3\frac{1}{2}$ miles northeast of Rimersburg station; 6 feet, light gray clay.

Country bank, 2 miles northeast of Wild Cat; $2\frac{1}{2}$ feet, quite free from sand.

At Huey a draft showing $7\frac{1}{2}$ feet of clay, top and bottom not seen.

Flint clay below the Lower Kittanning coal has been noted at various places south of the Clarion River from an area around Strattonville southwest to an area north of Sligo. In the past it was mined or stripped in several localities. The greatest activity was on the Finnefrock and Winkler farms two miles southeast of Piney and in the mines of the Sligo Fire Brick Co., two miles north of Sligo. Lines¹ gives details of the localities as follows:

Piney, $2\frac{1}{2}$ miles east of, on C. W. Mowry farm, prospect hole revealed 3 feet or more of fair-looking clay.

Piney, 2 miles southeast of, on P. B. Finnefrock and D. C. Winkler farms; several acres of clay have been stripped but very little is now exposed. The bed is reported to average 4 feet in thickness. In the hills on the U. S. Oppelt farm, south of the Finnefrock stripping, the clay is reported to be present also, although it has not been used.

Piney, 2 miles southwest of, on T. N. Whitman farm; old stripping in which clay was reported to average 3 feet in thickness.

Sligo, 2 miles north of, on C. B. McQueen farm; stripping and newly opened drift; average thickness about $3\frac{1}{2}$ feet.

Sligo, $1\frac{3}{4}$ miles north of, on J. B. Miller farm; old strippings.

Sligo, $2\frac{1}{2}$ miles northeast of; newly opened stripping on Mike Howard farm; exposed thickness 2 feet; reported thickness 5 feet. In two places just north of this point about one-half acre has been stripped.

Mechanicsville, 1 mile north of, on Clark Potter farm; prospect hole shows 4 feet or more of clay of inferior quality.

Elk City, $3\frac{1}{2}$ miles south of; bed on top of rise under light cover.

Piney, $2\frac{1}{2}$ miles southwest of, and Zion churches, 1 mile northeast of; a few fragments.

Piney, $2\frac{1}{2}$ miles southeast of, on road leading to Five Points schoolhouse.

Sligo, $2\frac{1}{2}$ miles northeast of and just southwest of schoolhouse; clay apparently of excellent quality.

¹ Lines, loc. cit., pp. 341-342.

Reidsburg, 1 mile north of, on road to Clarion.

Clarion-Williamsburg, road between; clay shows in several places, at some in considerable thickness, but of inferior quality.

Mechanicsville, $1\frac{1}{2}$ miles northwest of, on road to Clarion; 2 feet exposed.

Mechanicsville, $\frac{1}{2}$ mile east of, south of cross-roads; inferior quality, black and knotty.

Mechanicsville, 1 mile east of, on road to Waterson station; 3 feet exposed.

Mechanicsville, 1 mile east of, on north and south road at top of hill; bed under light cover.

Clarion-Strattonville, road between; several exposures.

Strattonville, $1\frac{1}{2}$ miles south of, and Rehoabeth Church, $\frac{1}{4}$ mile west of; 2 feet exposed; inferior.

Strattonville, 2 miles northeast of, on road to Fisher, at top of rise; bed under light cover.

Strattonville, 2 miles northeast of, near schoolhouse; small showing but clay apparently of excellent quality.

At the present time none of the Lower Kittanning flint elays south of the Clarion River are being used, probably because they have been found to be too high in iron.

The plastic elays under the Clarion coals are fairly thick and may be of use in the manufacture of buff face brick, sewer pipe or tile. Lines¹ notes their occurrence in a run near the schoolhouse about one mile northeast of the Zion churches where 5 feet or more of white elay are seen below each coal; at the road fork, half a mile south of Rockville, a 15 foot bed; 10 feet of clay on Leisure Run, $4\frac{1}{2}$ miles north of New Bethlehem.

Along Redbank Creek.—The lower reaches of Redbank Creek cut deeply into the Pottsville and lower sandy formations and the coals and clays lie high above the stream. No promising elays are seen near stream level. Passing up stream we find at St. Charles the plant of the McLain Fire Brick Co. utilizing a flint and plastic elay from the Mercer horizon which at this point lies 300 feet above the stream. This plant operates on the Armstrong County side of the creek and is described in Bulletin M 17. At Climax about 1 mile up stream are the plants of the Climax Fire Brick Co. One of these is on the Armstrong County side of the stream and one on the Clarion County side. The Mercer elay is mined near stream level on both sides about a mile up stream from the plants. The elay bed ranges from 6 to 12 feet in thickness and is irregular in its distribution of flint and plastic elays. The flint elay is of excellent quality and by combining it with

¹ Lines, loc. cit., p. 337.

varying amounts of the accompanying plastic clay various products are made. The bed is probably the same as that at St. Charles although it may not be continuous between the two points. See tests of this Mercer clay in Bulletin M 17, under Armstrong County (no. 193).

A down fold, the Fairmount syncline, crosses Redbank Creek between New Bethlehem and Hawthorn and carries most of the Pottsville beds below drainage, bringing the overlying Allegheny group near stream level. Three-quarters of a mile west of New Bethlehem the New Bethlehem Tile Co. operates a tile plant and uses Clarion shale and clay from the hill north of the plant. Under a thin coal, probably the Clarion coal, there lies about 15 feet of dark shale below which there is about 12 feet of shale and clay. No. 292 represents the average of the shale. It has fairly good plasticity and fair green strength. It fires to a buff to brown color with a firing range from cone 04 to cone 3. It is suited to the manufacture of face brick, conduits, and hollow tile. The company makes chiefly the two latter products.

These three companies were operating in 1940.

At Fairmount, 2 miles east of New Bethlehem, the Bostonia Coal and Clay Products Co. some years ago made hollow building tile. Their plant was north of the railroad and they used the Lower Kittanning clay which was mined west of the plant on the high bank. The Vanport limestone lies about 30 feet below the clay. This plant ceased operations in 1928.

At Hawthorn in former years the Hawthorn Pottery Co. made Bristol glazed stoneware using Middle Kittanning clay stripped along Town Run opposite the No. 2 mine of the Allegheny Coal Co. The clay was from 4 to 6 feet thick, white and plastic at the top and greenish and more sandy at the base. The upper clay was made into the smaller ware and the lower material used in the larger pieces. East of Hawthorn at Mayport, the Mayport Clay Works (F. B. Pope) mines and ships much Lower Kittanning clay from across creek in Armstrong County. An average sample of the material as shipped (no. 293) shows it to have good plasticity and a low green strength. It fires to a cream to gray color with a firing range from cone 06 to cone 13. It fused at cone 27. It is suited to the manufacture of No. 2 refractories or face brick. Sample 392, collected by Mr. Graeber, also represents this clay.

Summary.—Summarizing the clay resources of the county we might say that flint clay of the Mercer horizon is actively mined in the Climax and Lucinda areas. Lower Kittanning flint clay is known to occur at various localities and was formerly extensively stripped

but much of it is iron-stained and now it is little used. The more promising localities for it are near Sligo, Piney, and Clarion Junction.

Plastic clays ranging from high grade bond clays to buff-burning face brick and sewer pipe clays accompany the Clarion and the Lower Kittanning coals over most of the county. The Lower Kittanning clay has been used at Fairmount.

Brown and gray shales suitable for face and common brick are abundant throughout that portion of the county covered by the Allegheny or the Conemaugh strata. The only shale now in use is the Clarion shale at New Bethlehem.

Localities in Clarion County from which samples were obtained:

- 292. Shale. New Bethlehem Tile Company, New Bethlehem.
- 293. Plastic clay. Lower Kittanning bed. Mayport Fire Clay Company, Mayport.
- 378. Plastic clay. Upper Kittanning bed. Clarion Refractories Company, two miles southeast of Clarion.
- 379. Plastic clay. 2½ miles north of Spaces Corners, along the road.
- 380. Flint clay. Mercer bed. Niles Fire Brick Company mine, two miles east of Shippenville.
- 392. Plastic clay. Lower Kittanning bed. Mayport Fire Clay Company, Mayport.

The following analyses are from U. S. Geol. Survey, Bull. 315, p. 340, 1907. The analyses were made by P. H. Bates in the U. S. Geol. Survey testing laboratory at St. Louis:

- B 1 Flint clay from mine of the Sligo Fire Brick Company, on the McQueen farm; upper foot of the clay bed.
- B 2 Flint clay. Same locality as B 1, lower 2 feet of the bed.

Physical tests of Clarion County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point (cone)	Best burning range (cones)	Firing color	Suggested uses
292	20.1	3.7	6	105	5.7	02	18	05-1	Buff to brown	Face brick, hollow tile, conduits
293	23.8	4.0	7.5	100	8.3	11	27	07-11	Cream to gray	Fire brick, face brick
378	20.4	3.4	4	183	6.7	9	19	4-9	White to dark gray	Face brick, sewer pipe
379	23.0	5.1	5	195	6.8	9	28	1-9	Cream buff to gray	Face brick
380	19.8	2.7	2	36	5.6	11	34	02-11	White to gray	Refractories
392	24.0	5.7		135	5.7	9	28	1-11	White to gray	Face brick, No. 2 refractories

Chemical analyses of Clarion County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
379	6.02	60.43	7.40	1.05	20.56	.63	2.37			.07	.01	.08
380	13.52	44.92	1.82	.77	36.56	.35	.82	1.46	.20	.05	.09	.51
B 1	10.70	58.96	3.32		25.60	.70	.25	.15	.36	.07		.07
B 2	12.04	56.46	2.55		27.69	.42	.28	.06	.52	.09		.14

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Shaw, E. W., and Munn, M. J., Coal, Oil and Gas of Foxburg Quadrangle, Pennsylvania: U. S. Geol. Survey, Bull. 454, 1911.

Sisler, J. D., Bituminous coal fields of Pennsylvania, pt. 2: Pennsylvania Topog. and Geol. Survey, Bull. M 6, pt. 2, 1926, pp. 135-152 describe Clarion County coals.

CLEARFIELD COUNTY

Clearfield County lies east of Jefferson and Indiana Counties and north of Cambria County. Its southeastern border is just west of the Allegheny Front and its surface is therefore a high plateau. The higher portions are 2,200 feet above sea level; much of the surface is around 1,600 to 1,700 feet. The stream channels are about 1,200 feet above the sea and most of the major streams occupy deep valleys. The northern half of the county is largely a mountainous area, heavily wooded. The southern half is less rugged and is given over to coal mining and agriculture. The chief streams are Bennett Branch draining the northwestern part of the county; the West Branch of the Susquehanna River flowing in a northeasterly direction across the middle of the county; Chest, Little Clearfield, and Clearfield Creeks flowing from the southern border northward into the Susquehanna River; and Moshannon Creek bordering the county on the southeast. Clearfield Mountain is the high plateau between Bennett Branch and the Susquehanna River.

The strata exposed in the county are the lower half of the Conemaugh group, the Allegheny group, the Pottsville series, and the Mauch Chunk and Pocono beds. The Conemaugh strata are present in the DuBois area, in the southwestern townships, and in scattered hilltops in the southern half of the county. The Allegheny group

occupies most of the surface in the western and southern portions. The Pottsville series, chiefly heavy sandstones, forms the surface strata along Clearfield Creek and parts of the other southern streams; areas east of Clearfield Creek; most of the Susquehanna valley; large areas in the high plateau north of the Susquehanna River; and on Bennett Branch north from Winterburn. The Mauch Chunk and Pocono rocks are exposed in the anticlinal areas, as along Clearfield Creek, along Susquehanna River east of Frenchville, and in many places in the Clearfield Mountains.

From the standpoint of clay resources the important horizon lies at the base of the Allegheny group and in the upper 50 feet of the Pottsville series. As in some other counties there is here some confusion regarding the exact correlation of the beds in these horizons and it seems not always possible to fix the age of some of the clays. Most of the good clays in this zone are believed to be of Mercer age and the overlying heavy sandstones are termed the Homewood sandstone of the Pottsville. Lack of a good marine limestone such as the Vanport, which only occasionally is found, and the thickening and thinning of sandstone lenses make correlation difficult. The average intervals between the principal coals of the county as given by Ashley¹ are as follows:

Name of bed	Average interval Feet	Aver. thickness	
		Ft.	in.
Bakerstown		thin	
Brush Creek	100	thin	
Mahoning	45	thin	
Upper Freeport (E)	65	2	6
Lower Freeport (D)	40	3	0
Upper Kittanning (C')	60	2	0
Middle Kittanning (C)	55	2	0
Lower Kittanning (B)	45	2	6
Brookville (A)	90	1	6
Mercer (Pottsville)	50	1	0

These sedimentary strata are compressed into a series of parallel folds extending from southwest to northeast across the county. The major folds are:

Houtzdale syncline, through the Philipsburg-Houtzdale region.

Laurel Hill anticline, through the Irvona-Madera-Wallaceton area, bringing up much Pottsville strata.

An irregular synclinal belt from the southwestern corner of the county to Clearfield.

Chestnut Ridge anticline, McGees Mills northeast in the high plateau area north of the Susquehanna River. Brings up much Pottsville and Mississippian strata.

Punxsutawney syncline, DuBois to Penfield.

¹ Ashley, G. H., Bituminous Coal Fields of Pennsylvania, Pt. 2: Pennsylvania Topog. and Geol. Survey, Bull. M 6, p. 164, 1926.

The Susquehanna River naturally divides the county into a southern and a northern half. These main divisions will be used in discussing the clay resources.

South of the Susquehanna River

Southwest corner of the county, west of Chest Creek.—This district extends from Chest Creek on the east to the Indiana County line on the west, including the portion of Susquehanna River from Cherry Tree to McGees Mills and a small part of Cush Creek which enters the county from the west. The valley of the Susquehanna River above Burnside and the uplands between the Susquehanna and Chest Creek are made up of Conemaugh strata, the higher points reaching about to the Saltsburg sandstone. In these lower Conemaugh beds there should be good brick shales and at the position of the Brush Creek coal and below there are possibly some clays of better grade but none of these have been developed.

The Susquehanna valley from Burnside north, the area west from this part of the river, and the valley of Chest Creek are cut from strata of the Allegheny group and the Upper and Lower Freeport coals are exposed. No clays have been worked with these coals but from a sample of a clay below the Upper Freeport coal just south of Cherry Tree (see no. 353, Cambria County) it would seem that they could be used for brick manufacture. On Chest Creek near the mouth of Rogues Creek an anticline brings above stream level the coals of the lower Allegheny and the Pottsville sandstones. Use might be made here of the clay under the Lower Kittanning coal or good clays might be found at the Brookville horizon or below in the Pottsville. This locality seems to be the most promising one in the district for clay development.

The Freeport coals are mined north from Burnside and occur along Cush Creek. Toward McGees Mills lower coals appear and at McGees Mills the Lower Kittanning and Brookville and the underlying Pottsville sandstones are seen. The Lower Kittanning coal is known to be underlain by 4 to 8 feet of clay and the Brookville by 4 to 8 feet of somewhat sandy clay. Neither has been developed. West from McGees Mills near Sidney a flint clay has been observed, supposedly in the Mercer horizon. So far, however, no workable flint clay has been uncovered in this district. Experience with Conemaugh shales and clays and with Kittanning clay at Patton (see Cambria County) would lead one to think that the shales in connection with the Kittanning and Brookville clays near McGees Mills or near Rogues Creek could be developed.

The New York Central Railroad follows Chest Creek, Cush Creek and the upper Susquehanna River; the Pennsylvania Railroad follows Cush Creek and thence down the Susquehanna to McGees Mills.

Between Chest and Clearfield Creeks.—The area between Chest and Clearfield Creeks is one of active coal mining and is well served by branches of the Pennsylvania and the New York Central Railroads. The surface rocks of the higher lands between the streams are of lower Conemaugh age; the stream valleys are cut from Allegheny beds. Clearfield Creek from Coalport northward, and the greater part of Little Clearfield Creek valley cut down into the Pottsville beds and therefore expose on the higher banks the lower portion of the Allegheny group. The coals mined in this region are chiefly the Lower Freeport, Lower Kittanning, and to a smaller extent the Brookville or A coal. The clay beneath the Lower Freeport seems to be thin and is not used. Beneath the Lower Kittanning coal there is a thicker clay and in some places a thin flint clay but neither has been developed. Beneath the Brookville and in the 10- to 50-foot interval below it good plastic clays and flint clays have been found at many places and that horizon is the valuable one in clay prospecting.

The development of clays has been chiefly along the Clearfield Creek valley. Between Coalport and Irvona a clay was collected from the dump of a coal mine, probably the Lower Kittanning horizon. This clay (no. 124) had good plasticity and fair green strength. It fired to a light to dark buff color with a firing range from cone 04 to cone 9. It fused at cone 26. These tests indicate that the clay is a low grade fire clay suited best to the manufacture of buff face brick or fire-proofing. No doubt many of the underclays now thrown out could be utilized in the manufacture of such products.

North from Madera, Clearfield Creek cuts deeply into the Pottsville series, exposing also some of the underlying Mississippian beds. Between Madera and the junction of Little Clearfield and Clearfield Creeks flint clays of value have been mined from the Mercer horizon and plastic fire clay from the Clarion horizon. Mr. J. H. Hance collected samples of the clays in this area some years ago and these were tested by the U. S. Bureau of Standards. The tests are included in the tables of tests. Notes on them appear in Pennsylvania Geological Survey Bulletin M 10, p. 64, from which the following information was obtained. At Carnwath on a branch of the New York Central Railroad, 5 miles west of Potts Run, a plastic clay from the Carnwath No. 2 mine, under the Lower Freeport coal, was tested (H 4). This clay fused at cone 25. It is not a good refractory clay but might be used in the manufacture of buff face brick. H 1 is a flint clay from the Jno. Brotherlin mine at Faunce. This clay retained a porous structure to 1475°C. and fused at cone 33+. H 3 is a flint clay from the Faunce mine at Faunce. It also retains a porous structure to 1475°C. It fuses at cone 33. These Faunce clays are

excellent flint clays and are probably of the Mercer horizon. Flint clay is known also at Chase, three miles north of Faunce. H 5 is a plastic clay from the Clarion horizon at Krebs. It vitrified at 1200°C . and fused at cone 20. It seems suited to the manufacture of buff face brick. H 6 is a shale from Krebs. This showed good plasticity, vitrified at 1175°C ., and fused at cone 8. It is suited to the manufacture of building brick.

Fire clay has also been mined from two horizons at Clearfield Junction. It is evident that there is considerable good Mercer flint clay between Clearfield Junction and Madera and that there is also good plastic clay below the Lower Freeport, Lower Kittanning, and the Clarion coals, these being classed as No. 3 fire clays or as buff brick clays.

East from Clearfield Creek.—The area between Clearfield and Moshannon Creeks is underlain chiefly by the Allegheny group of strata but Laurel Hill anticline brings up a large area of Pottsville strata between Clearfield Creek and West Decatur. The Pottsville also appears along Moshannon Creek below Munson to the mouth of the creek. The southern part of this district, between Irvona and the Centre County line, is an area of Allegheny beds with Conemaugh strata on the hilltops. This area is crossed by the Pennsylvania Railroad through Utahville. Interest in the clays of this area would center around the extreme southeast corner of the county. Here the lower portion of the Allegheny group forms the surface rocks and there is a possibility that the same flint clay found at Dean and Blandburg a few miles southwest in Cambria County might be uncovered. This clay lies at the base of the Allegheny group or in the upper Pottsville series. Thence northeast through Houtzdale to Philipsburg in the Houtzdale syncline the surface rocks are chiefly of the Allegheny group, and coal mining is very extensive. No clays are utilized although doubtless there are some good plastic underclays suitable for buff face brick manufacture.

The Osceola Silica & Fire Brick Company on Route 53 at the west edge of Osceola Mills uses hard and soft underclays from the Morgan Run district for making fire brick and shapes. The product is burned in 16 downdraft rectangular kilns.

From West Decatur and Blue Ball west across a highland to Clearfield Creek is an area of exposed Pottsville strata with some of the overlying Allegheny beds. This has been for many years an area of intensive clay mining, the chief activity being from three miles west of West Decatur to Burly, and along Sanbourn Run and Morgan Run. The correlation of the coals and clays in the area is uncertain but there seems to be a Clarion coal with an underlying plastic clay, a

Brookville coal with a plastic clay, and a Mereer coal with an excellent bed of flint clay below it, generally 6 to 8 feet thick but in places 12 to 15 feet.

The Harbison-Walker Refractories Co. acquired fire clay deposits in the Burly district in the northwest corner of Decatur Township about 1902 from the Philipsburg Firebrick Co. and is an important producer in that district.

The General Refractories Co. operates a large fire brick plant at Blue Ball and controls much of the clay mining in the district, but other firms also mine and ship clay to many points in the State. The mines at Burly are connected by long tram roads with the plant at Blue Ball. Shaw in Bull. M 10 gives notes and tests on three samples from this area, samples nos. 51, 52, and 53.

No. 51 is a plastic clay from the Reed mine $1\frac{1}{2}$ miles west of the Blue Ball plant. This is a Clarion clay and the sample represents the upper three feet of a 6-foot clay bed, the lower three feet being more sandy. This is a No. 2 fire clay fusing at cone 29. It is mined and used at the General Refractories plant at Blue Ball.

No. 52 is a flint clay from the McClaren mine of the General Refractories Co., $4\frac{1}{2}$ miles west of Blue Ball. The clay is 8 feet thick and is overlain by 18 inches of soft clay. It fuses at cone $31\frac{1}{2}$ and Shaw considers it to be a good No. 1 fire clay with good burning properties. It is probably a Mercer clay.

No. 53 is a nodular flint clay from a mine $\frac{1}{2}$ mile south of the McClaren No. 10 mine. It is a Mercer clay separated from the Mercer coal by 3 feet of black shale. The clay is 4 to 5 feet thick. It fuses at cone $32\frac{1}{2}$ and is an excellent flint fire clay.

During the present survey sample no. 280 was collected from a General Refractories Co. mine three miles west of Blue Ball. This clay is a flint clay 2 to 4 feet thick and overlain by a coal $2\frac{1}{2}$ feet thick. It fired to a light cream color with a firing range from cone 06 to cone 13. It fused at cone $32\frac{1}{2}$. It is an excellent flint fire clay.

Sample no. 266 represents the flint clay of the Sanbourn Run region used years ago at the plant of the U. S. Refractories Co. at Barrett. This clay fired to a cream color with a firing range from cone 06 to cone 13, and fused at cone 28. It was used in connection with other Barrett clays for making refractory products. It is evident that there are several horizons for plastic and flint clays in the district. Near Burly an average section may be about as follows although there is much irregularity.

Feet	
—	sandstone
$2\frac{1}{2}$	coal
2-5	plastic clay
15	sandstone
1	coal
3	plastic clay
15-20	sandstone
4-10	flint clay

Southeast from Clearfield along Roaring Run, plastic and flint fire clays are developed at Barrett, Woodland, and Bigler, along the Pennsylvania and the New York Central Railroads. The main clays worked are the Woodland clay, chiefly of flint quality and probably Mereer age, and the Bigler clay, a plastic clay of possibly Clarion age. The following samples represent the clays of this area. Nos. 54 and 63 described and tested by Shaw (Bull. M 10); H 12-17 collected by Hance and described in Bull. M 10; 264, 265, 267, 268 collected during this investigation by the author. East of the Clearfield boro line $2\frac{1}{2}$ miles, at Barrett, the Harbison-Walker Refractories Co. operates a fire brick plant, mining both flint and plastic clay near the plant. This plant was owned successively by the U. S. Refractories Company and the North American Refractories Company. No. 264 is the plastic clay, the Bigler bed, mined just above the plant. This clay varies from 4 to 8 feet thick. It has good plasticity and fair green strength. It fires to a cream to spotted gray color with a firing range from cone 06 to cone 3, and it fuses at cone 20-26. It is suitable for face brick as well as for a bond in fire brick. No. 265 is the flint clay at Barrett. This is about 5 feet thick and lies below the Bigler clay. It is probably the same as the Woodland clay. It fires to a cream color with a firing range from cone 06 to cone 13. It fuses at cone 29. These clays (264 and 265) have not been used at the Barrett plant since its acquisition by Harbison-Walker Refractories Co. The mines near Barrett formerly operated by the U. S. Refractories Co. have been abandoned.

At Woodland, the Harbison-Walker Refractories Co. fire brick plant uses semi-flint clay from one bed, the Woodland clay. This is mined at the same level as the plant and north of the road. No. 267 is the average run of flint and semi-flint as brought from the mine. The plasticity is low and the green strength is low. The clay fires cream to buff with a firing range from cone 06 to cone 13. It fuses at cone 30. This average sample (267) has little meaning as, in mining, the Harbison-Walker Refractories Co. keeps the flint and semi-flint clay separate. The fusion point, cone 30, is not representative of the clay from this mine. Actually the Woodland mine has been known for many years for the high quality of its flint and semi-flint clay, representative samples of which fuse respectively at cone 33 and 32 or higher. Mr. Hance collected samples from this same Woodland mine and they are described as follows. H 13, upper hard clay fusing at cone 33; H 16, lower soft clay, fusing at cone 32+; upper hard clay of lower grade. H 17, fusing at cone 30. He also notes a clay, H 15 from the Plane mine, Woodland. The middle hard part of this remained porous at 1475°C. and softened at cone 31. This clay is said to lie under the C' coal. This may be identical with the Bigler bed of Barrett.

One mile northeast of Woodland the General Refractories Co. mines a plastic clay from the Clarion horizon, underlying 10 inches of Clarion coal, in the Walker mine. This clay (no. 54) is 9 feet thick. It is said by Shaw to be a fair No. 2 fire clay overfiring between 1350° and 1400°C. It fuses at cone 29. It is mined and shipped to the Blue Ball plant.

At Bigler, the Williams Grove Clay Products Corp. manufactures face brick from a bank of brownish shale 25 feet thick together with a plastic fire clay mined beneath the shale. This Bigler clay is about 10 feet thick. A sample of it (no. 268) shows fairly good plasticity and fair green strength. It fires to a cream to speckled color with a firing range from cone 06 to cone 7. It fuses at cone 20-26. It is an excellent clay for the manufacture of face brick, sewer pipe, or conduits. Combining it with the shale a variety of colors and products can be made. Across from this plant at Bigler the Harbison-Walker Refractories Co. has two drift mines and a stripping on a bed of plastic clay ranging from 3 to 16 feet in thickness and apparently of Clarion age. The mine contains a small amount of flint clay that fuses at cone 30-31.

Half a mile south of Bigler on Route 322 W. D. Little of Philipsburg, in 1940 is stripping 18 feet of shale and 20 inches of coal to get 12 feet of gray underclay. The clay is delivered by truck to fire-brick plants in Clearfield County. Mr. Little is mining clay by drift on the Allport cut-off two miles east of Bigler and on Morgan Run; also near Lucinda in Clarion County. He is reported to ship fire clay to Ontario, Canada.

The Shimmel mine operated by Harbison-Walker Refractories Co., at Wallaceton produces both soft and flint clay from a bed which is probably the Mercer. From Hance's sample, H 12, it is seen that the flint clay is very refractory, fusing at cone 33+. The soft clay, H 14, is a buff-burning fire clay fusing at cone 29. However, the owner reports that the average plastic clay fuses about cone 29, and the small amount of flint clay occurring in pockets has an average fusion point of cone 30-31.

In the area north from Philipsburg the strata are chiefly Allegheny with small patches of Conemaugh shales. Shales for brick making are frequently seen and no doubt some good under clays accompany the coals mined in that section. No clay development has taken place, however, in that region. Along Moshannon Creek about a mile below Viaduct the General Refractories Co. operates a clay mine on the Centre County side of the stream (see nos. 56-57, Centre County). These clays are supposedly in the Mercer horizon and they might be expected on the Clearfield County side of the stream as well, since the Moshannon flows in the Pottsville beds from Munson to its mouth.

Little is known of the clays in the uplands between the Moshannon and the Susquehanna in the Kylertown region. Small samples of fairly good-looking plastic clays have been seen from the region north and northwest of this place and it would seem as if good clays including flint clays should be expected near the heads of the small streams which flow into the Susquehanna in that area.

Susquehanna River from McGees Mills to the Clinton County line

McGees Mills.—West Branch of the Susquehanna, being the main transportation route across the county, is the seat of many communities and industries. It cuts a deep and very winding course through the Allegheny and the Pottsville strata, flowing on the Pottsville beds for its whole extent and cutting into the Mississippian strata below Frenchville.

In the vicinity of McGees Mills the clays exposed are the Lower Kittanning, Clarion, Brookville, and Mercer. Ashley in Atlas 65, page 107, notes plastic clay 4 to 8 feet thick at McGees under the Lower Kittanning coal. On the map on page 55 he indicates a Clarion flint clay outcrop $1\frac{1}{2}$ miles northwest of McGees, and another Mercer flint clay at Sidney, west of McGees.

East from McGees, clays and shales of the lower Allegheny group appear frequently along the road. Half a mile north of Mahaffey along the main road a section shows as follows:

10 ft.	shale and sandstone
4 "	sandstone
13 in.	coal
2 ft.	clay
—	irregular sandstone

Near the mouth of Laurel Run and just east of the Camp meeting grounds the section is:

Feet	
2	light shale
$0\frac{1}{2}$	dark shale
4	clay (no. 118)
3	iron-stained buff shale
2	thin gray shale
—	sandstone

The clay exposed here (no. 118) shows fair plasticity and high green strength. It fires to a light to dark buff with a firing range from cone 06 to cone 9 and fuses at cone 20. It seems suited to the manufacture of buff face brick, paving brick, fire-proofing, and sewer pipe.

Just south of Curry Run on the New York Central Railroad a dark shale makes a prominent cliff. This shale (no. 125) lacks plasticity

but fires to a good red color with a firing range from cone 02 to cone 9. It fuses at cone 14. If mixed with clay or surface soil to increase its plasticity, brick could be made from it. On the hill road just east of Curry Run the following section is exposed:

Feet	
—	sandstone
20	splintery shale (no. 120)
1	black shale
15	colored clays with a 3-ft. gray layer (no. 119)
10	thin sandstone and shale with thin coal
6	shaly sandstone

The shale (no. 120) has fair plasticity and low green strength. It fires to a good red color with a firing range from cone 06 to cone 7. It is suitable for the manufacture of red face brick. No. 119 represents a three-foot layer of gray clay interbedded with colored clays. This clay has fair plasticity and low green strength. It fires light buff to dark buff with a firing range from cone 06 to cone 9 and fuses at cone 20. It could be used in making buff face brick. Combinations of the shales and clays of this section would allow a variety of products to be made.

Bells Landing.—In the vicinity of Bells Landing east of Curry Run, flint clay occurs with the Lower Kittanning and the Brookville coals, and plastic clays and shales are found at many horizons in the Allegheny group. North of Bells Landing 0.8 mile along the road to Grampian a prospect tunnel exposes a semi-flint clay under one foot of coal with white sandstone above. This clay (no. 121) has fair plasticity and low green strength. It fires light buff to gray with a firing range from cone 06 to cone 12. It fuses at cone 26. It is suited to the manufacture of buff face brick or low grade refractories. It has a thickness of four feet and is about 1½ miles from the New York Central Railroad. In Bulletin M 10 Shaw gives tests on samples from the Bells Landing area as follows:

No. 70, the 6-foot plastic part of a 10-foot clay under the Lower Kittanning coal on the property of D. F. Bell, 1 mile north of Bells Landing. This clay fused at cone 20 and is a No. 3 fire clay.

No. 71, 4-foot flint clay part of the same bed. A siliceous flint clay fusing at cone 29 and classed as a No. 2 flint fire clay.

No. 79, a flint clay of the Brookville horizon in outcrop on the Passmore Estate along the bank of the river, 1 mile below Bells Landing. It fused at cone 35 and is a No. 1 flint clay. This clay is about 6 feet thick.

No. 80 is a flint clay from the same horizon and taken from the Hoyt Estate, 2 miles below Bells Landing. This clay is 7 feet thick. It fused at cone 35 and is a No. 1 flint clay. These two clays may be of the Mercer horizon.

No. 78 represents a gray clay from 2 to 4 feet thick, lying below the Lower Frecport coal on the property of the Good Coal & Clay Co.,

near Bells Landing. This is a plastic, red-burning clay which the company mines and ships to Patton for the manufacture of tile.

No. 81 is a sample of a 9-foot bed of shale below the Lower Kittanning coal in Mine No. 1 of the Pennsylvania Coal & Clay Corp., $\frac{1}{2}$ mile below Bells Landing. This shale is suited to the manufacture of face brick or tile.

Lumber City.—A plant was built one mile down river from Lumber City in 1910-11 and operated until 1917 by the George S. Good Fire Brick Co. It was purchased in 1917 by the Bickford Fire Brick Co. Within a few months this company was merged with the Crescent Refractories Co., and in 1929 the Crescent was merged with the North American Refractories Co. This last company is still operating the plant, which has 14 periodic kilns and a capacity of about one million brick per month. Clays mined in the Anderson Creek district are used at this plant.

At Lumber City the Mercer flint clay has been mined near river level, in a bed about 6 feet thick. A test of this clay from the Ross mine is given in Bull. M 10. It retains a porous structure to 1475°C. and fuses at cone 33.

Curwensville.—At Curwensville is the immense fire brick plant of the North American Refractories Corp. (formerly the Crescent Refractories Co.). It uses clay mined to the north of the plant in the Anderson Creek district to be discussed later. Between Curwensville and Clearfield, shales and some poor clays in the lower part of the Allegheny group are to be seen.

Clearfield.—In the borough of Clearfield there are many exposures of shales and clays and their correlation is somewhat uncertain. It seems probable that they represent the section from the Brookville down to the Mercer but that the usual thickness of sandstone is missing and is replaced by unusual amounts of clay and shale. Several beds of gray clay from 3 to 6 feet thick are exposed and also several irregular beds or masses of dark flint clay of poor quality. These clays and shales are well suited to the manufacture of brick and other products. No plastic or flint clays seem available at Clearfield. Some of the flinty material was used years ago but it seems too impure to be of any value at present.

Along the railroad on the north side of the river at Clearfield the following section is seen:

Ft.	in.	
1	8	coal
	4	clay parting
1		coal
7		shale
1	6	coal
6		buff shale with masses of dark flint clay.

Just west of and somewhat below this section 3 feet of gray clay is exposed. At a cut 200 yards north of the Pennsylvania Railroad freight house the section shows:

Ft.	in.	
8		sandstone
7		thin black shale
0	10	coal
5	8	concealed
1		coal
9		dark slaty flint clay

Ashley¹ gives the following section just above the railroad station at Clearfield:

Ft.	in.	
		coal outcrop
5		light drab clay
4		clay or shale, hard and flint-like
5		light drab clay
1/2-2		coal
4-6		drab clay
	3	coal
2		clay with iron nodules
4		clay with a few iron nodules
	6	iron concretions
3		hard flinty clay
7	6	sandstone
6-10		dark drab shale
	8-14	coal grading into dark shale
5	6	hard yellow clay
	9-18	coal
8		bluish drab clay
	2	coal
1	4	hard dark shaly clay
	6	coal
1		clay to tracks
7	6	concealed
8		sandstone to river.

Ashley states that the upper bed of this section lies 102 feet below what is thought to be the Lower Kittanning coal.

At Riverview, just west of Clearfield, the Clearfield Clay Products Co. manufactures face brick and tile from shale and plastic clay mined at the plant. The clay is probably the Lower Kittanning. It ranges from 3 to 7 feet thick and is overlain by a thin coal and this by 10 feet of bluish shale. The clay (no. 263) has good plasticity and fair green strength. It fires cream to gray with a firing range from cone 010 to cone 06 and fuses at cone 20-26. It is suited to the manufacture of face brick. The shale (no. 262) has fairly good plasticity and low green strength. It fires to red to brown and has a firing range from cone 06 to cone 01. It can be used in face brick mixtures. At present (1940) the shale is not used and no red brick are made.

¹ Bituminous Coal Fields of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M. 6, Pt. 2, p. 162, 1926.

The plant in Clearfield boro formerly operated by North American Refractories Co. has been dismantled.

Just east of Clearfield the Robinson Clay Products Co. operates a sewer pipe plant, using a six-foot bed of plastic clay which underlies the Middle Kittanning coal. The mine is on the hillside east of the plant and the clay is transported by aerial tram to the plant. This clay was tested by Shaw (Bull. M 10) and found to be a No. 3 plastic fire clay burning satisfactorily up to 1300°C., above which it overfires. It fuses at cone 20. The sample number is 74.

At this plant the company makes sewer pipe, wall coping, septic tanks, underdrain, etc. from a mixture of shale and fire clay; and flue lining, chimney pots, and stove pipe from fire clay only. Most of the product is machine-molded.

The plant has 27 periodic kilns with inside diameters of 35 and 36 feet. It is believed to be the largest producer of these products in the State.

Shawville to Karthaus.—East from Clearfield down the river to Shawville, the exposed rocks are of Pottsville age and are chiefly sandstones. Some of the lower Allegheny coals have been mined above the river but none of the clays are utilized. At Shawville a series of clays, shales, and thin coals is exposed, probably of the Mercer horizon. The section at the west end of the railroad tunnel shows:

Feet	
4	dark shale with iron nodules
1	coal
8	gray clay
0½	coal
6	shale
8	sandstone
3½	shale
0¾	coal
2	gray clay
3	thin gray shale

At the east end of the Shawville tunnel the following strata are seen:

Ft.	in.		Ft.	in.	
48		sandstone	4		shaly sandstone
2		dark shale	0	4	coal
0	5	sandstone	2		clay
1½		coal	2		dark cannely shale
4½		sandy shale, nodular	1		coal
0	8	coal	2		gray sandstone
10		dark clay, sandy at top	3		soft sandy clay
0	1	coal			
2		clay shale			
1		hard shale			
4		sandy shale, nodular			

These shales and clays have not been used. No tests were made of them but it is evident that there are good materials for brick making

but it is unlikely that any of the clays are of fire-clay quality. The same beds are seen with very irregular structures between Shawville and Croft. Just east of Croft a cut shows:

Ft.	in.	
—		shale
0	6	coal
6		shale
2		light clay
0	9	sandstone
1	8	dark sandy shale
3	6	micaceous sandstone
7		sandstone, nodular
0	5	coal
3	6	shale
3	6	light clay, sandy at top.

At Surveyor Station 10 feet of thin bedded nodular shales are seen underlain by 25 feet of heavy bedded sandstones. These are probably below the beds of the Croft section.

Pottsville sandstones are exposed through Frenchville and Deer. Below Deer $1\frac{1}{2}$ miles the base of the Pottsville is uncovered and a good exposure of the red shales of the Mauch Chunk group is seen. These red shales have been used elsewhere for brick making and no doubt the less sandy layers here could be used.

From Deer on eastward to Karthaus and beyond to the edge of the county, the river flows on Pottsville rocks. The Allegheny group is high on the hills and near Karthaus the Lower Freeport and Lower Kittanning coals have been mined. A plastic clay of good quality was formerly mined by the General Refractories Co. at the Cochran soft clay mine, Karthaus. According to Shaw (Bull. M 10) this clay (no. 58) was a fair quality No. 3 fire clay fusing at cone $26\frac{1}{2}$. Its horizon is not known but it is probably Lower Kittanning clay. A fire brick plant at Karthaus has been dismantled.

North of the Susquehanna River

North of McGees Mills and Bells Landing.—North from the Susquehanna River in the western part of the county the surface rocks are chiefly Allegheny beds, and the Pottsville appears in some of the tributaries, as Whiskey, Clover, and Laurel Runs. Clays appear under most of the coals in this area, especially under the Lower Kittanning coal, but none have been used. Shaw tested a plastic clay from the Lower Freeport horizon from the property of the Madeira Hill Coal Co. at the head of Clover Run. This clay (no. 76) was five feet thick, four feet being soft and one foot being harder. It fused at cone 17 and can be classed as a No. 3 fire clay. An accompanying shale was tested as no. 77 but this proved to be of doubtful value.

Just east of Grampian along Little Anderson Creek the Pottsville appears and $1\frac{1}{2}$ miles east of the village flint clay has been mined. The section shows:

Feet	
—	sandstone
1	coal
2	shale
3	nodular flint clay
4	smooth flint clay

Sample 122 represents the average of both types of clay. It has a firing range from cone 06 to cone 13 and fuses at cone 34. It has been mined by two adits, carried under the road by a tram, and loaded onto cars on the Pennsylvania Railroad nearby. It is an excellent grade of flint clay and probably is the Mercer clay. It is owned by the Harbison-Walker Refractories Co. Sample 64 of Bull. M 10 is from the same property.

Anderson Creek.—Anderson Creek rises north of Rockton, flows southeast, and enters the West Branch at Curwensville. It has cut deeply into the high plateau area formed by the Chestnut Ridge anticline. The creek flows in a deep gorge along which Pottsville, Mauch Chunk, and Pocono beds are exposed. The Buffalo, Rochester & Pittsburg Railroad (now B. & O.) passes along this valley from Curwensville to Rockton. On the high plateau on both sides of the stream the upper portion of the Pottsville series is exposed, including the Mercer beds, and in this horizon valuable flint clays are extensively mined. On the east side of Anderson Creek the flint clay is mined by the North American Refractories Corp. about three miles northwest of Curwensville and high above the valley of Anderson Creek. These mines are connected with the plant at Curwensville by a long tram road. The clay is exposed in a large stripping face and several mine entries. The flint clay is overlain by a coal bed usually less than one foot thick, over which are heavy sandstones. The clay ranges from 3 to 12 feet thick, thinning being due to sandstone rolls coming down from the roof. The upper two feet of the clay is generally nodular or diasporic and is the best quality. The remainder is block or marbleized flint clay. They are usually mixed together but for some purposes the nodular clay is kept separate. Sample no. 260 represents the average of a 10-foot face of the clay. This clay fires light to dark buff with a firing range from cone 01 to cone 13. It fuses at cone 33. It is a very high grade flint clay and is made into fire brick at Curwensville.

A large area of flint clay extends from the west side of Anderson Creek to beyond Little Anderson Creek. Mining has been carried on near the edge of the valley and the clay let down inclines to the rail-

road along Anderson Creek. Tipples are located at Bloom and Glendale. Operations are chiefly confined to an area about $1\frac{1}{2}$ miles southwest of Anderson and west of Little Anderson Creek. Here the North American Refractories Corp. operate the Draucker mine and Harbison-Walker Refractories Co. the Pierce and Spencer mines. The clay is carried down to a branch of the railroad which leads up into the Little Anderson Creek valley. The clay is from 3 to 7 feet thick and is overlain by the usual thin coal. No. 298, a sample from the Pierce mine, burns to a cream to buff color with a firing range from cone 06 to cone 13. It fuses at cone 32. Much of the clay in this area has enough plasticity so that it can be made into fire brick without the admixture of any other bond clay. The sample above however appeared to be a true flint clay of good quality.

About a mile west of these mines there are also old stripping pits exposing at least five feet of good flint clay, with the thin coal bed overlying it.

Along the Buffalo, Rochester & Pittsburgh Railroad on Anderson Creek the red shales and sandstones of the Mauch Chunk formation crop out between Millikens and Bloom, exposures at Bloom showing 45 feet of red shale and sandstone. North of Glendale in the heart of the anticline, Pocono sandstones appear along the creek. At Anderson the Pottsville beds dip down again to rail level and at Rockton, Allegheny beds are in evidence with many dark shales. Near Rockton the Lower Kittanning coal, Vanport limestone, and Clarion or Brookville coal horizons are exposed but no clays of value were noted. Clays however are to be expected with these coals. In cuts along the railroad just northwest of Luthersburg sections are shown about as follows:

Feet	
25	sandy shales with many concretions
15	thin dark shales slaty at base
20	concealed
2	coal
6	clay (no. 258)
2	sandstone, bouldery
6	sandstone and shale

The coal mined nearby is probably the Upper Kittanning bed. The clay (no. 258) has good plasticity and fair green strength. It fires to a salmon to gray color with a firing range from cone 06 to cone 01. It fuses at cone 20-26. It is best suited to the manufacture of face brick or hollow tile. At C & M Junction Conemaugh rocks are exposed and along the railroad the Brush Creek limestone and the shales below it down into the Mahoning horizon are to be seen. Good brown shale 12 feet thick is present and at another point 7 feet of yellow and purple clays. All these have the appearance of good brick clays.

Anderson Creek to the northeast corner of the county.—This district is a rough wooded mountain tract underlain chiefly by Pottsville beds. It is a region without railroads and with few good highways. Flint clays have been reported from various parts of the district and some prospecting has been done but, to date, no good clays have been uncovered for development.

DuBois to Tyler.—DuBois lies in a synclinal area of Conemaugh rocks extending from Winterburn to Troutville. South from DuBois to C & M Junction and to Eriton, Stanley, and Sykesville good brick materials are to be found in the lower Conemaugh. These are used at Sykesville (see Jefferson County). Near DuBois the Upper Kittanning and the Lower Freeport coals are mined. The clays below these coals are thin and are not used. At Falls Creek the Hydraulic Press Brick Co. makes face brick from shales and clays of the lower Allegheny group (see Jefferson County). North from Falls Creek, Wolf Run and the railroads along it are chiefly in Jefferson County and the clays of this stretch have been discussed under that county. East of Wolf Run, in Clearfield County, it is probable that a thin clay and a blue shale underlie the Clarion coal, and higher up in the hill-slope the Lower Kittanning clay may be present.

Northeast from DuBois the valley of Bennett Branch is followed by the Pennsylvania and the Buffalo & Susquehanna Railroads. At Sabula near the tunnel on the Buffalo & Susquehanna Railroad the following section is seen:

Feet	
33	olive shale (no. 248)
3½	dark thin shale with flat iron nodules
1	Brush Creek limestone
1	coal
24	crumbly clay (no. 249).

A similar section is seen on the Pennsylvania Railroad. The shale (no. 248) has good plasticity and fair green strength. It fires red to brown with a firing range from cone 010 to cone 06. It is suited to the manufacture of face brick or hollow tile. The clay (no. 249) has fair plasticity and green strength. It burns to a red color but fuses at the low temperature of cone 9 and is of doubtful value. This clay contains limy nodules which are hard to eliminate.

At Winterburn greenish shales of fair quality occur and coal has been mined but no good clays were seen. At Penfield the Lower Kittanning coal has been extensively mined. The clay below this coal in the Penfield No. 1 mine is slaty and of doubtful value. Fifteen feet above this mine entry is an opening possibly on the Middle Kittanning coal. Under this coal there is a sandy clay 2 feet thick (no. 251) that has good plasticity and green strength. It burns buff to gray with a

burning range from cone 06 to cone 01. It fuses at cone 27. This clay would make satisfactory fire brick of medium quality but is too thin. Just west of the station on the B. & S. Railroad four or more feet of clay occur beneath one foot of coal. This clay (no. 150) has good plasticity and fair green strength. It fires to a dark buff but has a very low firing range and is of doubtful value. East of Penfield station shales occur above a fresh-water limestone but no tests were made of them. At Tyler the Lower Kittanning coal is mined but no clay of value is known to accompany it. Shales and some thin clays west of Tyler along the railroad probably belong to the Middle and Upper Kittanning horizons. Material for brick making is available but no clays of greater value seem to be present.

Summary

The good flint clays in Clearfield County occur almost altogether in the upper beds of the Pottsville. These clays are very high grade and are made into fire brick at Curwensville, Clearfield, Barrett, Woodland, and Blue Ball. The two important areas for flint clay are between Blue Ball and Clearfield and centering around Anderson Creek northwest of Curwensville. Soft fire clays and under clays suited to the manufacture of sewer pipe and face brick accompany many of the coals of the Allegheny group, especially the Clarion, Lower and Middle Kittanning. Shales suited to the manufacture of face brick and tile are very common throughout those parts of the county underlain by Allegheny and Conemaugh strata.

Besides the plants manufacturing fire brick, one plant at Clearfield makes sewer pipe, and one makes face brick and tile at Bigler.

Two brick plants operate just west of the county line in Jefferson County, one at Sykesville and one at Falls Creek.

Localities from which samples tested were obtained:

51. Plastic clay, Clarion bed. Reed mine, $1\frac{1}{2}$ miles west of West Decatur (Blue Ball).
52. Semi-flint clay. McClaren mine, $4\frac{1}{2}$ miles west of West Decatur.
53. Flint clay, $4\frac{1}{2}$ miles west of West Decatur.
54. Plastic clay. Clarion bed, 1 mile northeast of Woodland.
58. Plastic clay. Cochran mine. Karthaus.
60. Shale under L. Freeport coal. Pa. Coal & Clay Corp. No. 2 mine. Bells Landing.
63. Plastic clay, 3 miles southeast of Clearfield on road to Philipsburg.
64. Flint clay, 1 mile southeast of Grampian on P. R. R.
70. Plastic clay. Lower Kittanning bed, 1 mile north of Bells Landing.
71. Flint clay. Lower Kittanning, 1 mile north of Bells Landing.
74. Plastic clay. Middle Kittanning bed, Robinson Clay Products Co., 1 mile east of Clearfield.
76. Plastic clay. Lower Freeport bed. Madeira Hill Coal Min. Co., 6 miles northwest of Mahaffey at head of Clover Run.
77. Shale, same locality as no. 76.

- 78. Plastic clay. Lower Freeport bed. Good Coal & Clay Co., 1 mile from Bells Landing.
- 79. Flint clay. Brookville bed. Passmore estate, 1 mile east of Bells Landing.
- 80. Flint clay. Brookville bed. Hoyt estate, 2 miles east of Bells Landing.
- 81. Shale. Lower Kittanning bed. Pa. Coal & Clay Corp., No. 1 mine, $\frac{1}{2}$ mile east of Bells Landing.

The above numbers 51-81 were tested by Shaw and results given in Bull. M 10 of the Pa. Topog. and Geol. Surv., 1928.

- 118. Plastic clay, 0.6 mile east of Mahaffey along road.
- 119. Plastic clay, $\frac{1}{2}$ mile east of Curry Run along road.
- 120. Shale, $\frac{1}{2}$ mile east of Curry Run along road.
- 121. Plastic clay, prospect tunnel, 0.8 mile north of Bells Landing.
- 122. Flint clay, 1.6 miles east of Grampian.
- 124. Plastic clay from mine dump, between Coalport and Irvona.
- 125. Shale. N. Y. Cent. R. R., $\frac{1}{4}$ mile west of Curry Run.
- 248. Shale over Brush Creek limestone, Sabula.
- 249. Clay under Brush Creek limestone, Sabula.
- 250. Plastic clay, along railroad west of Penfield.
- 251. Plastic clay. Penfield No. 1 mine, Penfield
- 252. Plastic clay on B. & S. R. R., $1\frac{1}{2}$ miles west of Tyler.
- 258. Plastic clay on B. R. & P. R. R., $\frac{1}{2}$ mile northwest of Luthersburg.
- 260. Flint clay. Crescent Refractories mine, east side Anderson Creek.
- 261. Plastic clay. John Larsen coal mine, north of Bells Landing.
- 262. Shale. Clearfield Brick Co., Riverview, near Clearfield.
- 263. Plastic clay. Clearfield Brick Co., Riverview.
- 264. Plastic clay. Bigler bed. U. S. Refractories Co., Barrett.
- 265. Flint clay. Bigler bed. U. S. Refractories Co., Barrett.
- 266. Flint clay. Sanbourn Run. (U. S. Refractories Co.)
- 267. Flint clay. Harbison-Walker mine, Woodland.
- 268. Plastic clay. Williams Grove Brick Co. mine, Bigler.
- 280. Flint clay. General Refractories Co. mine, 3 miles west of Blue Ball.
- 298. Flint clay. Pierce mine, 4 miles northwest of Grampian.

The following clays, H 1 to H 17, were collected by J. H. Hance, tested by U. S. Bureau of Standards, and described in Bull. M 10, pp. 64-65.

- H 1. Flint clay, Jno. Brotherlin mine, Faunce.
- H 2. Flint clay, Good mine, Morgan Run.
- H 3. Flint clay, Faunce mine, Faunce.
- H 4. Plastic clay. Lower Freeport bed. Carnwath No. 2 mine.
- H 5. Plastic clay. Clarion bed. Krebs.
- H 6. Shale. Krebs.
- H 7. Flint clay. Ross mine, Lumber City.
- H 8. Flint clay. Ross-Bloom mine, above Curwensville.
- H 9. Flint clay. Stronach.
- H 10. Nodular flint clay. Stronach.
- H 11. Plastic clay. Stronach.
- H 12. Flint clay. Shimmel mine, Wallaceton.

- H 13. Flint clay, upper hard clay. Woodland mine, Woodland.
H 14. Plastic clay. Shimmel mine, Wallaceton.
H 15. Flint clay, middle hard clay. Plane mine, Woodland.
H 16. Plastic clay, lower soft clay. Woodland mine, Woodland.
H 17. Flint clay, upper low grade hard clay. Woodland.

The following clays C 1 to C 15 are described in Rept. H of the Pa. Second Geol. Survey and reprinted in Rept. H 7, pp 167-180, 1884.

- C 1. Upper or "shell" clay, Harrisburg Fire Brick Co., 2-3 mile west of Blue Ball.
C 2. Middle or "block" clay, same source as C 1.
C 3. Lower or "flag" clay, same source as C 1.
C 4. Flint clay. Hope Fire Clay Works, Woodland.
C 5. Flint clay. Woodland Fire Clay Works, $\frac{3}{4}$ mile west of Woodland.
C 6. Hard clay, $\frac{1}{2}$ mile southeast of Woodland.
C 7. Soft clay, $\frac{1}{2}$ mile southeast of Woodland.
C 8-15. Clays from the Clearfield Fire Clay Works, 1 mile east of Clearfield.

Physical test of Clearfield County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point (cone)	Best burning range (cones)	Firing color	Suggested uses
51	26.43	17.98*	4 $\frac{1}{2}$		24.90*	11	29			No. 2 fire clay
52	23.96	12.04*	2		25.35*	14	31 $\frac{1}{2}$			No. 1 fire clay
53	17.01	4.00*	3		8.42*	14	32			No. 1 refractories
54	24.99	15.13*	8		26.20*	11	29			No. 2 fire clay
58	24.66	12.66*	5		28.00*	11	26 $\frac{1}{2}$			No. 3 fire clay
60	23.27	17.60*	9 $\frac{1}{2}$		22.86*	1	15			No value
63	23.11	9.93*	2 $\frac{1}{2}$		26.90*	14	32			No. 1 fire clay
64	20.38	2.92*			15.77*	14	32 $\frac{1}{2}$			No. 1 fire clay
70	22.78	11.70*	10 $\frac{1}{2}$		22.66*	9	20			No. 3 fire clay
71	21.88	7.72*	2 $\frac{1}{2}$		9.47*	11	29			No. 2 flint clay
74	25.30	13.35*	4		24.50*	9	20			No. 3 plastic fire clay
76	22.58	13.57*	13		22.25*	6	17			No. 3 fire clay
77	20.85	10.63*	6		28.10*	6	15			Doubtful value
78	23.94	16.38*	4		30.01*	1	15			Red tile
79	24.50	12.30*	3		22.90*	14	35			No. 1 fire clay
80	4.14	10.85*	1		24.90*	14	35			No. 1 fire clay
81	21.49	8.69*	7		21.90*	14	18			Face brick or tile
118	26.2	6.0	6	342	11.8	4	20	07-6	Light to dark buff	Face brick, paving brick, sewer pipe
119	22.5	5.7	4	207	10.8	11	20	07-6	Light to dark buff	Face brick
120	21.7	3.4	5	106	8.1	1	11	07-4	Light to dark red	Red face brick
121	20.0	5.1	10	106	8.0	9	26	07-9	Light buff to gray	Face brick
122	18.5	2.5	4	41	9.2	11	34	07-11		Fire brick
124	19.9	5.2	9	207	9.0	1	26	07-6	Light to dark buff	Face brick, fire proofing
125	19.9	2.6	4	43	11.0	11	14	02-6	Light to dark red	
248	27.2	5.1	5	180	8.0	02	13	012-07	Red to brown	Face brick, hollow tile
249	25.1	4.5	3	189	3.6	02	9		Red	Doubtful value
250	23.1	5.5	4.5	167	5.1	05	31?		Dark to light buff	Doubtful value
251	23.8	6.1	6.5	200	6.2	05	27	07-02	Buff to gray	Fire brick
252	26.6	4.9	6	189	8.1	02	14	010-02	Red to brown	Face brick, hollow tile, conduits
258	33.6	5.3	9	172	9.1	02	22	07-02	Salmon to gray	Face brick, hollow tile

* Volume shrinkage.

Physical test of Clearfield County clays—Continued

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point (cone)	Best burning range (cones)	Firing color	Suggested uses
260	20.3	1.0	1.5	—	4.4	6	33	02-11	Light to dark buff	Fire brick
261	28.4	7.1	6	414	8.6	02	20	012-02	Buff to brown	Face brick, hollow tile, conduits
262	22.4	2.9	4.5	74	5.4	02	16	07-02	Red to brown	Face brick
263	20.1	5.0	7	189	4.3	4	22	012-07	Cream to gray	Face brick
264	19.6	5.4	4.5	171	4.4	02	22	07-1	Cream to gray	Face brick
265	18.0	.5	2.5	45	3.3	11	29	07-11	Cream	Fire brick
266	18.4	1.8	2.	—	4.9	11	28	07-11	Cream to buff	Fire brick
267	22.5	2.6	5.	—	6.6	6	30	07-11	Cream to buff	Fire brick
268	20.1	4.4	4.	163	4.1	02	22	07-4	Cream to gray	Face brick, sewer pipe, conduits
280	19.2	1.4	1.	low	5.6	02	32½	07-11	Light to dark cream	Fire brick
298	19.5	2.2	1.5	25	4.7	02	31½	07-11	Cream to buff	Fire brick
H1	12.4	5.1*			17.3*	6	33+			
H2	12.1	4.8*			11.3*	9	33			
H3	12.3	4.8*			12.8*	4	33			
H4	18.8	13.7*			16.5*	1	25			
H5	18.6	13.6*			15.1*	3	26			
H6	—	—			18.8*	4	8			
H7	13.2	5.4*			13.8*	3	33			
H8	13.7	5.5*			12.6*	6	32			
H9	12.7	4.9*			16.5*	4	32+			
H10	13.2	3.5*			8.6*	9	33			
H11	20.3	14.1*			20.8*	1	15+			
H12	13.3	5.9*			11.9*	6	33+			
H13	12.2	4.6*			16.6*	6	33			
H14	18.1	13.0*			16.1*	3	29			
H15	16.1	7.8*			3.0*	3	31			
H16	16.8	10.6*			18.1*	9	32+			
H17	12.3	4.3*			16.8*	4	30			
H18	18.2	12.6*			14.5*	6	29			

* Volume shrinkage.

Chemical analyses of Clearfield County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
71	6.78	62.19	2.45		24.56	.58						.23
74	7.39	59.03	4.23	.79	23.41	1.18	.70	1.09	2.54	.06	.01	.10
118	8.20	54.80	.15		30.35	1.00	.25					
262	5.51	56.30	8.03	1.05	20.98	1.42	1.49					
265	9.88	57.93	3.21	1.21	26.67	.67	.31		1.38			.58
266	14.56	40.78	4.80	1.32	38.81	.35	.73					
C 1	13.84	42.70	3.38	2.50	37.60	.11	.27		.73			
C 2	14.17	43.35	2.14	2.82	37.55	.08	.23		.23			
C 3	13.66	44.55	1.44	1.70	39.00	.02	.07		.53			
C 4	13.54	46.25	1.93		37.50	.16	.12		1.11			
C 5	13.73	45.45	2.27		36.12	.17	.34		1.29			
C 6	13.60	45.23	1.98		38.03	.16	.23		0.83			
C 7	11.58	46.18	2.25		36.88	.17	.31		2.76			
C 8	7.28	60.13	2.37		25.71	.11	.66		3.49		H ₂ SO ₄	FeS ₂
C 9	9.56	64.85	1.21		23.77	.19	.12		.34		.19	.06
C 10	13.61	50.15	.84		35.60	.11	.16		.07		.28	.03
C 11	6.58	67.95	1.98		20.15	.08	.21		2.04			
C 12	8.30	57.87	2.55		27.00	.11	.46		3.17			.03
C 13	11.40	53.56	2.24		28.82	.43	.60		1.80		.87	.13
C 14	7.79	61.00	2.34		25.80	Tr	.53		2.80		.38	.06
C 15	12.83	51.36	1.93	.50	31.25	.06	.26		.03		.38	.74

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CLINTON COUNTY

Clinton County lies north of Centre County. The part of it that lies northwest from Lock Haven is in general a high wooded plateau about 2,000 to 2,300 feet above the sea and about 500 to 1,500 feet above the principal streams. The dominating stream is the West Branch of the Susquehanna River. It enters the county at Karthaus, flows northeast to North Bend and then southeast to Lock Haven. Its bed is 600 to 800 feet above sea level and the hills rise on both banks 700 to 800 feet above the stream. The West Branch and its tributaries drain almost all the plateau portion of the county. Beech Creek along the south-central border of the county cuts back into the plateau near Monument where its chief tributaries are Twin, Big, and Monument Runs. The Pennsylvania Railroad follows the West Branch across the county from Lock Haven to Keating and thence west up Sinnemahoning Creek. The New York Central Railroad follows the West Branch from Keating up to Karthaus and another branch passes up Beech Creek to Monument and Orviston. A large

part of the plateau area has no railroads and the clays in the Carboniferous strata can be taken out only on tram roads built at great expense. Prospecting is difficult and expensive and no doubt much of the high land has been explored very little for clays.

The West Branch and all its main tributaries and also Beech Creek near Monument cut down into Pocono strata or into the underlying Devonian beds. Practically all the upland is covered with Pottsville strata, most of which are coarse white sandstones. Small areas of the Allegheny group, including a few coal beds, lie on the hilltops northwest of the river between Karthaus and North Bend; on the hills near the headwaters of Monument Run, and on the hills along Tangascootack Creek. The coals in these small areas of the Allegheny group have never been definitely correlated but it would appear that Brookville coal has been mined in the Tangascootack basin and near Renovo; that 70 feet above this bed there is a coal, probably Lower Kittanning, that has been mined in the Tangascootack area and at Bitumen, west of Renovo; and that the coal stripped near Spruce, in West Keating Township, lies 110 feet above the Lower Kittanning bed and is probably a Freeport coal.

The Pottsville strata also are difficult to correlate. In the 200 feet that make up this series there are three sandstones each about 50 feet thick. The upper has been called the Johnson Run sandstone, the middle the Kinzua, and the lower the Olean conglomerate. Between the upper and middle sandstones is an interval of about 20 feet in which there are several thin coals, shales, and clays. These coals are known as the Alton coals. Below the Kinzua sandstone and separating it from the Olean conglomerate is an interval of a few feet which carries a coal, shale, or clay known as Marshburg. The Alton horizon may be the equivalent of the Mercer and the Marshburg may be the Sharon. The chief fire clays of the county are generally considered to be of the Mercer or the Alton horizon but have sometimes been called Brookville.

The clay resources of the county will be discussed by districts, following down the West Branch from Keating to Lock Haven and then passing to the Beech Creek area.

Karthaus to Renovo

Between Karthaus and Keating the river is the boundary between Clinton County on the northwest and Centre County on the southeast. Small areas of Allegheny coals occur on the hills above the river and three miles north of Spruce one of the coals has been actively worked by stripping. Six feet of fire clay are said to be found between two benches of the coal but this clay has not been used or tested. In the hills southwest of Keating flint clay has been noted in the Pottsville

beds but no good bed of clay has as yet been discovered. West from Keating the Sinnemahoning Creek cuts deeply into Pocono strata and the Pottsville strata lie high in the hills. No flint clays have been noted in this area.

From Keating northeast to Renovo the plateau on both sides of the river carries Pottsville strata and on the northwest side a few patches of the Allegheny beds with their coals. The high divide between Cooks Run and Kettle Creek carries some of the Allegheny strata and Lower Kittanning coal has long been mined at Bitumen and carried down a plane to Cooks Run along the railroad. The clay under this coal has not been developed and little is known about it. On Shintown Run considerable prospecting has been done for flint and plastic clays. About two miles up and on the west side of the run a six-foot bed of good plastic clay has been uncovered on the land of Joseph Smith but it has not been worked. Flint clay has also been found in the headwaters of Shintown Run and has been dug into but never actually mined.

Drury Run, just west of Renovo, has been a source of much good flint and plastic clay. On the west side of the stream and about 2 miles above its mouth the North American Refractories Company (formerly the Elk Fire Brick Company) has a mine at which the following section was seen :

	Feet
Coal	1-4
Clay, shale and sandstone	4-6
Flint clay	3-4
Soft clay	3
Sandstone	—

This flint clay is of good quality and has been mined extensively and carried by tram to the railroad for shipment to the various plants of the company. High on the plateau on the east side of Drury Run and reached by a tram up Stony Run is a mine operated some years ago by the Queens Run Refractories Company. This mine has been abandoned and the tram removed. The company's plant at the junction of Stony and Drury Runs has been torn down. The section at the mines is as follows :

	Ft.	in.
Coal	0	30
Soft clay, not used (no. 278)	6	0
Coal	0	3
Flint clay, mined (no. 276)	4	0
Soft clay	3	0

The flint clay (no. 276) fires to a light gray with a firing range from cone 06 to cone 13 and fuses at cone 30. The upper plastic clay (no. 278) has good plasticity and low green strength. It fires cream to dark gray with a firing range from cone 01 to cone 7 and it fuses at

cone 19. This clay might be used for the manufacture of face brick, hollow tile, or conduits.

The plant at the mouth of Drury Run, built early in this century by the Renovo Fire Brick Co., was bought by the North American Refractories Co. in 1929. Fire brick and shapes of all kinds were made here formerly, but in 1940 the product is light-weight insulating brick, burned in 10 downdraft periodic kilns. Plastic clay from Queens Run and fire clay from Haneyville, Lycoming County are brought to this plant by truck. The Queens Run clay is ground to 220 mesh in the company's plant at Lock Haven before it is taken to the plant on Drury Run.

On Paddy Run, north of Renovo, there are old workings in flint and plastic clays but the mining in that valley has been abandoned.

The red clays and shales of the Catskill series are exposed along the river in the vicinity of Renovo and east to North Bend and beyond. A sample of the better portions of these red beds was taken (no. 277). This clay has fairly good plasticity and fair green strength. It burns to red to brown with a burning range from cone 010 to cone 06. It might possibly be used in the manufacture of red face brick. There is a great quantity of such red clay along the West Branch in Clinton County and much of it is at rail level. Just east of North Bend where the sample was taken, the following section of it was exposed:

	Feet
Red clay	10
Red and green sandstones	10
Red clay to highway	20
Red clay and sandstone to river	50

Tangascootack Creek

From Renovo down to the mouth of Tangascootack Creek no clays have been worked in the hills bordering the river. Tangascootack Creek heads a few miles north of Monument and flows northeast about 8 miles and joins the West Branch 2 miles above Farrandsville. The Lock Haven Fire Brick Company and later the Stowe-Fuller Refractories Company have carried on extensive prospecting and mining operations in this valley. A railroad was built up the valley almost to its head and both coal and clay were mined. Operations have largely stopped now; only a small amount of coal is trucked out and no clay is mined. The railroad has been taken up. Claims are made that the clay proved too high in iron to be of value. Owners of some of the properties in the valley say that there is still much excellent flint clay in the area. The clay mines lie chiefly along Bird Run south from the main Tangascootack Creek, and on the hills north of the creek and between it and Holland Run. Shaw gives tests of two of

these clays in Bull. M 10, correlating them with the Upper Kittanning and the Brookville horizons. In this report no. 45 represents a four-foot bed of flint clay from the Goose Hill mine of the Stowe-Fuller Company, below the Upper Kittanning coal. This clay fused at cone $33\frac{1}{2}$ and is a No. 1 flint clay. Sample No. 46 was obtained from the Wilson Hill mine of the same company. It is the plastic clay from a bed of plastic and flint clay below the Brookville coal. It fused at cone 26 and is classed as a No. 3 clay. The correlation of these clays needs further study and it is quite likely that they will prove to be of the Mercer horizon. The Goose Hill mine is idle.

Farrandsville

At Farrandsville the Harbison-Walker Refractories Company at one time operated a fire brick plant and mined flint and plastic clays on the high hill one mile northwest of the village. At the mines an exposure shows the following section:

	Feet
Light shale with some iron concretions	10
Dark shale with thin coal	$1\frac{1}{2}$
Soft sandy clay (no. 281)	5
Soft sandy clay	—

This clay (no. 281) has good plasticity and fair green strength. It burns to a cream to gray color with a burning range from cone 04 to cone 13 and it fuses at cone 27. It is suited to the manufacture of fire brick. Apparently about 50 feet lower, a stripping pit and old mine expose the following section:

	Feet
Bluish gray shale	10
Coal	$3\frac{1}{2}$
Black shale	$0\frac{1}{4}$
Crumbly soft clay	2
Flint clay, blocky or nodular	$1\frac{1}{2}$ -3
Soft gray clay grading into sandstone	$1\frac{1}{2}$
Sugary sandstone	2

Queens Run

East of Farrandsville Queens Run comes in from the north and the Queens Run Refractories Company has carried on extensive operations on the high plateau along its West and Middle Branches. The mines along West Branch of Queens Run are reached by a tram road about 3 miles long. The section shows strata about as follows:

	Feet
Sugary sandstone, thin-bedded	2-6
Coal with some black slate	$1-2\frac{1}{2}$
Flint clay	$1\frac{1}{2}$ -3
Plastic or semi-flint clay	$1\frac{1}{2}$ -3

In one stripping the material shipped consisted of one foot of weathered flint, 2 feet of marble flint and 2 feet of soft clay. Shaw in Bull. 10 gives tests of the flint and soft clay from these mines as follows: No 47 is the upper bench or flint clay portion of the bed. It fused at cone 33 and is considered to be a No. 1 flint clay. No. 48 represents the lower bench or soft clay. It fuses at cone 31 and is a fine quality No. 1 plastic fire clay. On the Middle Branch on a 3-mile tram road there are mines in flint and plastic clay. Sections show that under from 5 to 20 feet of sugary sandstone there is from 5 to 14 inches of coal and below the coal a bed of flint clay varying from 4 to 10 feet thick. Sample no. 274 is the average as mined. It fires to a cream color with a firing range from cone 06 to cone 13. It fuses at cone 30. Shaw gives the Brookville as the horizon for this clay but more likely it is the Mercer clay. The clay mines on Queens Run are now owned and operated by the North American Refractories Company. The clay is trammed to the mouth of the run, where it is shipped by rail to the company's plants.

Northeast of these localities, at the headwaters of Queens Run and along the Clinton and Lycoming County line, flint clays have been found. One such deposit is that of the Kelsey Mining Company about half a mile south of Haneyville on the Lock Haven-Lucullus road. They control 1,800 acres of clay land of which 150 acres is proven. Their stripping shows four feet of flint clay underlain by 3 feet of softer shaly clay. The flint clay is about one-half nodular. No. 279 is a sample of the good flint clay. It burns to a cream color with a firing range from cone 06 to cone 13. It fuses at cone 33. It is an excellent clay and is hauled by truck 7 miles to Waterville and shipped by the New York Central Railroad or is shipped from Lock Haven on the Pennsylvania Railroad. Shipments have been made to various fire brick plants in New York, Ohio, and Pennsylvania.

Beech Creek

Along Beech Creek, at Monument, the Harbison-Walker Refractories Company operates a large fire brick plant, using clay mined on the plateau up Twin Run and Monument Run. The Twin Run mine, $2\frac{1}{4}$ miles from Monument, is reached by a tram road up the east side of the valley. The section as seen in the strippings and in the mine is as follows:

	Feet
Shales	20
Thin coal	—
Dark blue shale	20
Coal	$\frac{1}{2}$ -4
Plastic clay (271)	$\frac{1}{2}$ -2
Flint clay (272)	2-4
Sandstone floor	—

The plastic clay (271) shows fair plasticity and low green strength. It fires cream to gray with a firing range from cone 06 to cone 13 and fuses at cone 32. It is not now used but seems to be an excellent fire clay. The flint clay (272) fires to a cream with a firing range from cone 06 to cone 13. It fuses at cone 31. It is a good flint clay and is used extensively. Up Monument Run half a mile and high on the east side the company has a mine probably on the same bed but yielding chiefly plastic clay. Some of the clay is normal crumbly plastic, some is platy, and some is somewhat sandy and micaceous. Sample 270 represents the average of this material. It has good plasticity and low green strength. It fires to a cream to brownish gray with a firing range from cone 06 to cone 13. It fuses at cone 29½. It is mined and carried to the level of the run on a long incline, thence to the plant by tram. Samples 49 and 50 in Bull. M 10 represent samples similar in location to 270 and 272 respectively.

Harbison-Walker Refractories Co. says that samples 270-272 evidently were not representative of the clay from these mines because samples of the plastic clay fuse at cone 28-29, and of the flint clay at cone 33.

In 1940 the company's output is hand-made fire brick and shapes, burned in round down-draft kilns.

Summary

The clay resources of the northern two-thirds of the county are excellent flint and plastic fire clays occurring in the upper part of the Pottsville series or perhaps in the lower part of the Allegheny group. The active mines are practically all near the tops of the plateaus and are reached by long trams or inclines. At present the most active localities are Queens Run and Monument. In the past, mines at Shintown Run, Drury Run, Stony Run, Paddy Run, at Farrandsville, and on Tangascootack Creek have been active but have been abandoned because the better material has been taken out and the remaining clay is said to be too siliceous or too high in iron. No doubt further drilling will uncover other deposits of value in the plateau region. The active fire brick plants of the county include the plants of: Harbison-Walker Refractories Company at Monument, the General Refractories Company at Beech Creek, and the North American Refractories Company at Lock Haven and Renovo. The plants and mines of the Queens Run Refractories Company are now (1940) a part of the North American Refractories Co. and the Stowe-Fuller Refractories Co. plant at Lock Haven was bought by the Robinson Clay Co. and dismantled.

Materials for the manufacture of other clay products, such as common brick and tile, are not abundant in northern Clinton County.

Plastic clays of the quality of No. 3 fire clays should be found in connection with the coal mining operations in the small areas of Allegheny coals and in the same areas there should be suitable shales. Probably the most accessible clays for making brick would be the red Catskill clays along the valley in the vicinity of North Bend and Hyner. Sample 277 represents a red Catskill shale exposed along the road near Hyner. This showed fairly good plasticity and fair green strength. It fired to a red to brown color with a firing range from 900° to 1,000°C. It could be used in making common or face brick.

South of the Allegheny Front

The southeastern third of the county lies in the zone of folded Appalachians and is made up of tilted and folded strata ranging from Upper Devonian, through the Silurian and into the Ordovician period. The trend of the folding is northeast-southwest and the various strata tend to crop out in bands aligned in that direction. Between Queens Run and Lock Haven the plateau front gives way to lower land and along the descending slopes the Catskill red beds appear as a narrow northeast-southwest belt crossing the county just below Queens Run. These are similar to those at Hyner and could be used in making brick. Southeast from the Catskill belt is a wide belt of Middle Devonian gray to greenish shales and sandstones. These form the rolling hills to the west of Bald Eagle Creek. Among these beds are gray, soft shales some of which could be used in brick making. The only test made was on a shale (273) across the river from Lock Haven at Lockport. This proved to have no satisfactory burning range and is held to be useless.

East of this belt is a band of Lower Devonian and Upper Silurian limestones. Bald Eagle Creek from Beech Creek to Lock Haven and West Branch east from Lock Haven follow this belt. East of the limestone is a belt of variously colored Clinton shales, dipping northwest and flanking the northwest slopes of Bald Eagle Mountain. These shales are in successful use at Castanea by the Lock Haven Brick and Tile Company. The blue and purple shale dips 45° to the northwest. In it are occasional limestone lenses which are discarded. The shale is trammed half a mile by a nine-ton Whitcomb gasoline locomotive to the plant. Here it is ground in American and Raymond pans, molded in a Raymond auger-machine and burned in 5 round, down-draft, coal-fired kilns. The product is a strong dark red face brick. This plant was idle in 1940. Sample 282 of this shale shows good plasticity and low green strength. It fires red to brown with a firing range from 1,000° to 1,200°C. It is suited to the manufacture of face brick, hollow tile, and sewer pipe. Similar shale should be found

on the northwest flank of Bald Eagle Mountain across the county and also along Cherry Run on the southeast flank of Nittany Mountain.

The General Refractories Company plant at the east side of Beech Creek borough makes fire brick and shapes from clay brought to the plant by rail from Clearfield County. The product is burned in a bank of 16 rectangular kilns. The North American Refractories Company plant in Lock Haven is on the river bank near the west end of the city. Clays from Queens Run are used for making all kinds of fire brick. The plant has 16 end-fired, down-draft, rectangular kilns.

The high sharp ridge of Bald Eagle Mountain is made up of resistant Tuscarora sandstone with some red shale. This crest is part of an eroded anticline of Medina sandstone. This sandstone makes the high rugged mountains of the south end of the county. Between the mountains are limestone valleys, Nittany, Nippenose, and Sugar. In these the Ordovician shales might be of use in brick making and the residual clays overlying the limestone might be of even greater value. Among the residual clays in the Nittany Valley to the south are plastic white residual clays. Similar clays might occur in Clinton County.

Localities from which Clinton County clays were obtained:

45. Flint clay, under Upper Kittanning coal. Goose Creek mine, Tangascootack Creek.
46. Plastic clay, under Brookville coal. Wilson Hill mine, 3 miles from Birds Run Station.
47. Flint clay. Queens Run Refractories Company, Queens Run.
48. Plastic clay. Queens Run Refractories Company, Queens Run.
49. Flint clay, under Brookville coal. Harbison-Walker mine, 2 miles northeast of Monument.
50. Plastic clay, under Brookville coal. Harbison-Walker mine, $\frac{3}{4}$ mile north of Monument.
69. Flint clay, under Brookville coal. George Smith property, Shintown Run.

Samples 45 to 50 and 69 were tested and described by Shaw in Bull. M 10.

270. Plastic clay. Harbison-Walker mine. Monument Run.
271. Plastic clay. Harbison-Walker mine. Twin Run, near Monument.
272. Flint clay. Harbison-Walker mine. Twin Run, near Monument.
273. Shale. Middle Devonian. Lockport.
274. Flint clay. Queens Run Refractories Company. Middle Branch, Queens Run.
276. Flint clay. Queens Run Refractories Company. Stony Run mine, northwest of Renovo.
277. Red clay. Catskill beds east of North Bend.
278. Plastic clay. Queens Run Refractories Company. Stony Run mine, northwest of Renovo.
279. Flint clay. Kelsey Mining Company, $\frac{1}{2}$ mile south of Haneyville.
281. Plastic clay. Harbison-Walker mine, Farrandsville.
282. Shale. Lock Haven Brick and Tile Company, Castanea.

Physical tests of Clinton County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point (at cone)	Best burning range (cones)	Firing color	Suggested uses
45	22.72	9.38*	2		21.00*	11	33½			No. 1 flint fire clay
46	23.28	16.70*	13		25.50*	9	26			No. 3 fire clay
47	23.57	13.34*	3		23.40*	11	33			No. 1 flint fire clay
48	24.34	12.17*	9		31.80*	14	31			No. 1 plastic fire clay
49	22.20	10.67*	3		26.00*	14	33			No. 1 flint fire clay
50	27.36	17.16*	7¼		32.75*	14	30			No. 2 fire clay
69	25.85	9.61*	6		22.05*	14	34			No. 1 flint fire clay
Tests 45-69 are from Bull. M 10. * Indicates volume shrinkage.										
270	21.1	3.9	3	71	7.10	11	29½	07-11	Cream to gray	Fire brick
271	21.2	3.7	11	55	6.40	11	32	07-11	Cream to gray	Fire brick
272	18.8	0.9	1	0	4.20	9	31	07-11	Cream to buff	Fire brick
273	20.4	2.4	3	63	1.6	05	12	none	Red to dark red	No value
274	16.4	2.0	3½	27	5.40	11	30	07-11	Cream to gray	Fire brick
276	17.8	1.6	2	1	5.80	1	30	07-11	Light gray to buff	Fire brick
277	17.4	3.6	10	112	3.70	02	13	012-07	Red to brown	Face brick
278	20.8	4.0	9	65	7.20	9	19	02-4	Cream to dark gray	Face brick, hollow tile, conduits
279	21.8	1.5	2	10	4.70	9	33	07-11	Cream	Fire brick
281	20.8	4.7	5	153	6.20	6	27	05-11	Cream to gray	Fire brick
282	21.3	4.5	6	90	5.90	6	12	07-4	Red to brown	Face brick, hollow tile, sewer pipe

Chemical analyses of Clinton County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
50	4.57	44.88	5.12	0.56	37.70	1.13	1.11	—	—	—	.61	—
69	13.72	41.88	3.92	1.56	30.84	.02	1.09	1.04	5.32	.21	.06	.09
282	5.74	55.48	—	—	—	—	—	—	—	—	—	—

Selected references to the geology of Clinton County.

Chance, H. M. (and Ashburner, C. A. and Platt, F.), Report on Clinton County, including description of the Renovo Coal Basin by C. A. Ashburner and notes on the Tangascootack coal basin by F. Platt: Pennsylvania Second Geological Survey, vol. G 4, 1880.

Shaw, J. B., Fire clays of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 10, 1928.

Sisler, J. D., Bituminous coal fields of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 6, pt. 2, 1926; pp. 191-193 describe the coals of Clinton County.

COLUMBIA COUNTY

Columbia County lies between Montour and Luzerne Counties in the Ridge and Valley section, with the Pocono sandstone forming the edge of the Allegheny Plateau at its northern border. The northern half of the county is drained by Fishing Creek which joins the North Branch of the Susquehanna River above Catawissa. The southern townships are drained by Catawissa and Roaring Creeks which flow north and west into the Susquehanna River. The North Branch crosses the middle of the county from east to west through Mifflinville, Bloomsburg, and Catawissa.

The sedimentary rocks of the county are folded and the axes of the folding extend in a direction north of east. The various formations, therefore, cross the county in east-west belts. They range in age from coals and shales of Pennsylvanian age in two coal basins, down to Middle Silurian shales in an anticlinal valley north of the Susquehanna River. The greater part of the county is underlain with Middle Devonian and Catskill beds.

The coal basins are on the southeastern and southern borders of the county, synclinal basins of anthracite enclosed in a rim of Pottsville, Mauch Chunk, and Pocono strata. One very small area of coal measures lies east of Beaver Valley on the county line. It is a westward tongue of the Middle Anthracite Basin of Hazleton. The larger coal basin centers around Centralia near the southern border. It is a portion of the Mahanoy-Mount Carmel Basin. The anthracite beds are accompanied by dark shales but these are too nearly slates and are too dark to be of use in brick making. Fire clays do not accompany the anthracite beds.

Around the coal basins is a low rim of Pottsville sandstone and beyond that a lower valley or area underlain by soft red Mauch Chunk shales. These shales form a belt along the north edge of the Centralia Basin, a valley between the Pocono sandstone ridge to the north and the Pottsville ridges to the south. In the Beaver Valley Basin a larger area is underlain by the Mauch Chunk beds, including Beaver Valley and Hubbelville. A high Pocono ridge, Nescopeck Mountain, encloses this Mauch Chunk area on the north, and on the west, Catawissa Mountain. The softer Mauch Chunk shales are of value in brick making. Railroads cross the Beaver Valley and brick-yards could be established there.

East from Orangeville a ridge of Pocono represents the western end of the great Northern Anthracite Field which broadens eastward. In Columbia County, the splitting of this Pocono ridge encloses a very small area of Mauch Chunk shale east of Fishing Creek Post-office. On the outer side of the Pocono sandstone rims of these coal

basins there stretch wide lowlands underlain by the red sandstones and shales of the Catskill formation. A wide belt of this formation lies north of Little Mountain, west of Catawissa Mountain, and north of Nescopeck Mountain. The Susquehanna River cuts through these beds at and below Catawissa. A second belt surrounds the Pocono ridge of Shickshinny Mountain and crosses the county through Orangeville. A third wide area covers the northern townships at the foot of North Mountain. These Catskill strata are largely red sandstones and sandy shales, but there are beds of soft or weathered shale of sufficient thickness and pure enough for brick manufacture.

Adjoining the Catskill areas and with slightly lower topography are wide belts of gray and green shales and sandstones of the Middle Devonian. There are four of these belts. The widest lies between Orangeville and Benton and extends east-west across the county; the second extends west from Berwick on the north side of low ridges of Helderberg limestones; a third extends from West Berwick through Mifflinville and Rupert, along the south bank of the Susquehanna River; a fourth lies west of Numidia in the southern part of the county. These areas carry interbedded gray sandstones and shales with occasionally gray or green shales free from sand layers and valuable for brick making.

At Mifflinville, J. L. Turner & Company operate a brickyard using these Devonian shales, the only brickyard in the county. The brick plant at Bloomsburg was dismantled about 1930.

East and west through Bloomsburg is a low valley underlain by Middle Silurian shales, the Bloomsburg red beds. This is an anticlinal valley flanked on north and south by a low ridge of Helderberg limestone and some Oriskany sandstone. The valley and its rim terminate eastward at Berwick. The red Bloomsburg shales are used in many counties in brick making and are easily accessible in this valley, especially around Bloomsburg.

Selected references to the geology of Columbia County:

White, I. C., The geology of the Susquehanna River Region in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour and Northumberland: Pennsylvania Second Geol. Survey, vol. G 7, 1893.

Willard, B., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

CRAWFORD COUNTY

Crawford County lies south of Erie County. It is within the glaciated portion of the Allegheny Plateau province, the uplands rising to 1,800 feet above the sea, but more generally 1,200 to 1,600. The topography is of a mild rolling type with few rock outcrops and a general cover of glacial drift.

The exposed rock strata in the county consist of interbedded shales and sandstones ranging in age from the Chemung of the Upper Devonian, through the Mississippian, and into the Pottsville division of the Pennsylvanian. The total exposed thickness is about 800 feet.

The southern hills are generally capped by sandstones and conglomerates of the Pottsville group. The northern valleys are underlain by the Chemung and Venango shales and flagstones. The remainder and greater part of the county is underlain by shales and sandstones of the Mississippian period. Many of these show such close alternations of shale and thin sandstones that their use in brick making is prohibited, but no doubt there are areas where soft bluish clay shales may be found free from sandstone contamination. These could be used in the manufacture of red brick and tile.

The glacial drift covers the county with a blanket of yellow and bluish boulder clays, sands and gravels ranging from a few feet to perhaps 100 feet in thickness. The thicker deposits represent fillings of preglacial valleys. The deposits of yellow or blue clay when not contaminated with too many boulders or sand pockets could be made into satisfactory common red brick or tile.

No use is made of the shales or the glacial clays for brick making and no tests were made of them. It seems unlikely that there are present any ceramic materials of higher grade than common brick shales and clays. The chief description of the geology of Crawford County is that of I. C. White. The geology of Erie and Crawford Counties: Pennsylvania Second Geological Survey, Report Q 4, 1881.

CUMBERLAND COUNTY

Cumberland County lies north of Adams and York Counties in the Great Valley, between Harrisburg and Shippensburg. Its northern border is the southernmost of the folded Appalachian ridges, Kittatinny (North or Blue) Mountain, a sharp upturned ridge of Tuscarora quartzite of Lower Silurian age. South from its base lies the wide plain of Ordovician shale and limestone, a part of the Great Valley. This plain is bounded on the south by South Mountain, a mass of Cambrian quartzites and pre-Cambrian igneous rocks.

Shale belt

The belt of upper Ordovician (Martinsburg) shale crosses the northern part of the county in a band three to six miles wide, bounded on the north by Kittatinny Mountain and on the south by the outcrop of underlying limestones. About two miles north from Carlisle on the New Bloomfield road a roadside sample (327) of light buff shales showed fair plasticity and green strength, and fired to a salmon to red-brown color with a firing range from 1100° to 1200°C. These shales are suited to the manufacture of face brick. Six miles north from Carlisle on this same road dark gray shales in a shale quarry (sample 328) show fair plasticity and green strength. They fire salmon to good brick red with a firing range of 1100° to 1150°C. Brick could be made from them but they are not as satisfactory as sample 327.

Outcrops of light to dark buff or gray shales are common throughout the shale belt, and from the tests it seems that common and face brick could be made from them. The softer, lighter-colored shales should be selected, especially in places where they are well weathered.

Limestone belt

The limestone belt crosses the central part of the county from east to west in a six-mile wide band bounded on the north by the more hilly shale belt and on the south by the mountainous Cambrian and pre-Cambrian mass. Clays in the limestone belt are residual colored clays resulting from the decay of the underlying limestone. The distribution and thickness of such clays is very irregular.

Sample 325 represents a residual clay taken from the roadside in the eastern part of the county, four miles from Dillsburg on the road to Carlisle. The outcrop shows a series of highly tilted quartzites, quartz schists, limestone bands, and shales, probably Cambrian. The sample was taken from a 25-foot band of deeply weathered shale. The plasticity was good and the green strength high. It fires to a red or reddish brown with a firing range of 1000° to 1150° C. It could be

used as modeling clay or in the manufacture of floor tile, art tile, roofing tile, or flower pots.

Sample 329 is a red residual clay over the Ordovician limestones near the western limits of Carlisle. It shows excellent plasticity and high green strength. It fires light to dark brick red with a firing range of 1000° to 1200° C. It could be used as a modeling clay and in the manufacture of floor tile, art tile, pottery, or flower pots.

These two samples indicate that this limestone valley contains interesting residual clays of excellent quality for a variety of uses.

At least two brick plants operated on the residual limestone clays, both near New Cumberland. Mr. E. E. Fleurie made common brick at New Cumberland until 1932. Clay was dug from an area at least 800 feet square and the brick burned in five or more beehive kilns. The clay here is of excellent quality, being almost white and free from iron impurities.

Near the Fleurie brick plant, another plant was operated by Messrs. Leiby and Landis. The type of clay was apparently the same as at the Fleurie plant. This plant ceased operations about 1925.

At one time, three or four brick plants were active in or near Carlisle. These have all been abandoned for close to twenty years. A Mr. McDonald, of Carlisle, operated one of the last plants there. Common brick were made also about one mile north of Shippensburg but operation was abandoned many years ago.

South Mountain

South and southwest of Mount Holly Springs lies the mountainous belt known as South Mountain, rising 800 feet above the surrounding lowlands. This mass is made up of a core of pre-Cambrian crystalline rocks flanked by folded and faulted Cambrian strata, chiefly quartzites and phyllites. Deep weathering of the thinner-bedded quartzites and of the phyllites has yielded white and gray residual clays of value.

The principal area of development has been one to two miles southwest of Hunters Run or 5 miles south of Mount Holly Springs along Mountain Creek. Mountain Creek here flows along the strike of a synclinal belt of the Tomstown dolomite of upper Cambrian age. Northwest of the creek the mountain rises steeply and is made up of Antietam quartzite and Harpers phyllite dipping to the southeast. Farther up and farther into the mountain the more resistant Montalto quartzite lies below the other beds. The residual clays lie on the lower slopes of the mountain under a cover of mountain wash and colored clays. Driving entries into the mountain discloses first the colored clays, then the good white varieties and finally a foot-wall of quartzite which may be the resistant Montalto beds.

One company is active in the Hunters Run area. This is the Philadelphia Clay Co. The mine lies one mile southwest of Hunters Run, at Toland and on the west side of the creek and railroad. The mine entry cuts directly into the mountain for 750 feet, where headings are driven off to the northeast and southwest along the strike of the clay bed. The clay bed is wedge-shaped, having a maximum width of about 300 feet near the surface and thinning to 40 or 50 feet at a depth of 200 feet, on which level the present mine is working. Small chambers (20' by 20' by 10') are stoped on a pitch of 45° or 50° from the individual headings that branch from the main entry. The timbers are removed from these stope chambers and the clay bed

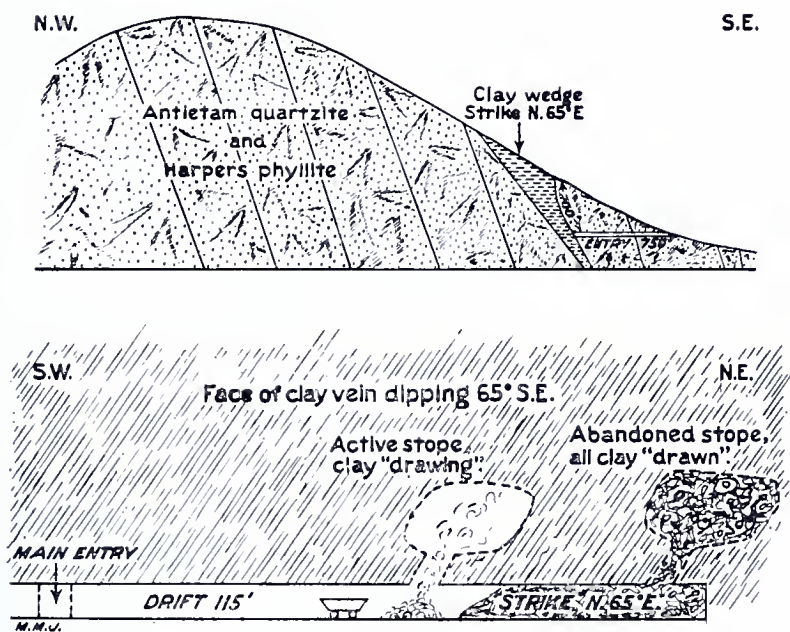


Figure 4. Cross sections of Philadelphia Clay Co. mine.

allowed to "draw", thus accumulating on the floor of the heading, where it is shoveled into mine cars. Approximately all the recoverable clay is "drawn" in such a stope in a month or two. That part of the heading is then abandoned, and new stopes made closer to the main entry, thus using a retreating system. The present mine was begun in 1938. More than 10 other mines have been opened, all on higher levels, since the company was first organized in 1894. Operations have extended half a mile in two directions from the plant.

The crude clay, which makes 80 percent of the product, is stored on a large stock pile for shipment to cement plants. Approximately 30,000 tons of crude clay are mined each year. The clay to be refined is trammed by mule and dinkey engine to the mill 300 feet from the entry, where it is washed in a bank of twelve paddle washers. The

washed clay passes through $\frac{1}{2}$ -inch and 60-mesh screens and finally over a stretched silk screen at a pitch of 80° which makes a product of minus 325 mesh. This product settles in large tanks and is then pumped to the filter presses, which eliminate most of the water. The filter cake passes through a pug mill, is then dried, and finally bagged, like flour, for shipment to paper mills.

The crude clay is white and plastic. It carries a few limonite stains, nests of coarse silica, and a few quartzite pebbles and lumps. All of this can be readily removed by washing but some finer silica is difficult to remove. The iron content rarely is more than one-half to one percent. Tests made by Shaw on the crude clay (326) from the bins show it to have very good plasticity, a low green strength, and to fire to a light cream to light gray color. Its burning range for vitrified ware is 1200 to 1250° C. and he suggests that it could be used for a cream body as it is, and for white body if refined. His further tests are as follows:

Water of plasticity	35.9%	Volume of air shrinkage	13.3%
Shrinkage water	8.9%	Linear air shrinkage	4.3%
Pore water	27.9%	Fusion, Cone 20	
Slaking time, minutes	26	Modulus of rupture, lbs.	27
Maximum linear fire shrinkage 10.8% at 1250° C.			

The Universal Atlas Portland Cement Company mine (formerly the Medusa and earlier the Sandusky Portland Cement Co.) is no longer active. The Philadelphia Clay Co. supplies the clay for Universal's cement plant at West York, Pa. The mine, which they operated till about 1930, is located three-quarters of a mile southwest of the Philadelphia mine and on the same ridge. The entry extends 580 feet down a steep incline, then flattens out into side headings. The clay shows a more schistose structure than that at the Philadelphia mine. It is white to gray in color, and was shipped without refining, to the cement plant of the company at West York, where it was used to whiten the portland cement. Tests made by Ries on this clay are as follows: Fired at 1150° C. it showed 6.4 percent absorption and 15.9 percent porosity. Fired at 1300° C. it had 0.1 percent absorption and 1.2 percent porosity. It burned buff at the lower temperature and was steel hard. At the higher temperature it burned gray.

The same company owns the former property of G. N. Gochnour about three-quarters of a mile west of Mount Holly Springs on the northwest slope of South Mountain. Early in the 1930s, Mr. Gochnour had driven several monkey drifts and shafts and claimed to have found 30 feet of clay in a shaft and 30 feet additional in some drilling, and also said the bed was proved horizontally for 200 feet. Mr. Gochnour sold his property about 1937. The clay is apparently a

good grade of white plastic clay. Thirty years ago on the property adjoining this on the west, and owned by Mr. Nickey, clay was taken out and used in making white brick and chimney brick at the plant of the Mount Holly Brick Co. at Mount Holly Springs. The Mount Holly Brick Co. was abandoned in 1908. Mr. Goodyear, whose land adjoins the old Gochmour property on the east, also mined residual clay at one time, and sold manganiferous clay to the Asper Tile Co. up to about 1933.

Several clay properties in the Mount Holly region were once active but have long been abandoned. They probably worked out the clay or ran into too much sand. Some built quite elaborate washing plants before recognizing the irregular, pockety nature of such residual clays. Descriptions of these plants are given fully in Bulletin 708 of the United States Geological Survey. Abstracts from this bulletin are given below.

The Cumberland Clay Co., which had the most elaborate plant of any, operated a large deposit about 1 mile east of Upper Mill. It operated for only five years, was abandoned in 1925 and the property (now 1940) is owned by John Fahnestock of Mount Holly Springs.

The Henry Clay mine was near Henry Clay, 2 miles southwest of the Medusa mine. It was worked by tunnels and shafts and the clay was sent to the Mount Holly Brick & Clay Co. at Mount Holly Springs. It was abandoned in 1908.

The Holly Clay Corporation had a large open pit operation on the northwest side of South Mountain, 2 miles east of Mount Holly Springs and 2,000 feet south of the Reading Railway. The pit showed 15 feet of overburden and 12 to 15 feet of clay. The clay was grayish white, mottled with limonite in places. It carried streaks of white sand and angular lumps of quartzite. The crude material was passed through a log washer, thence into a short trough to separate the stones from it. It then was sent to a Dorr classifier and then the clay and water were taken by pipe line to the washing plant where the mixture was passed through a Dorr hydroseparator, 50-foot sections of trough, a Dorr thickener, a filter press, and dryer. Sodium carbonate was added in the log washer to deflocculate the clay, and sulphuric acid to neutralize the alkali as the clay left the trough. The plant is said to have had a capacity of 60 tons of washed clay in 24 hours.

Tests of the clay are as follows:

	Crude		Washed	
Temperature (°C.) -----	1150	1300	1150	1300
Absorption (percent) -----	3	0.5	8.4	1.5
Porosity (percent) -----	10	2	19.5	3.4
Color -----	Buff	Gray	Cream-white	Gray-buff
Hardness -----	Steel hard	Steel hard	Steel hard	Steel hard

Tests of a washed sample showed linear air shrinkage 2.26 percent. At cone 8 (1290°C.) linear fire shrinkage was 14.12 percent and color grayish white. At cone 15 (1430°C.) linear fire shrinkage was 10.15 percent, the absorption 0.6 percent and the color grayish white.

This plant was abandoned in 1923, after operating only 3 or 4 years. According to local report the pit ran into too much sand.

Summarizing the clays of the county it is seen that there are brick shales in the northern shale belt, red-burning residual clays for pottery or tile making in the limestone valley belt, and white residuals in the South Mountain region.

Physical tests on Cumberland County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking in minutes	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point at cone	Best burning range (cones)	Firing color	Suggested uses
325	36.9	5.7	4	160	11.1	1	11	07-1	Brick red to red-dish brown	Floor, roofing, art tile and flower pots
326	35.9	4.3	26	27	10.8	6	20	4-6	Light cream to light gray	In cream or white bodies
327	24.9	3.0	8	108	9.9	02	12	02-4	Salmon to red brown	Face brick
328	19.6	5.2	9	140	4.4	1	13	02-1	Salmon to brick red	Brick
329	35.8	10.6	90	675	9.8	1	19	07-4	Light to dark brick red	Floor, art tile, pottery, pots

Chemical analysis of Cumberland County clay

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂	K ₂ O	MnO	P ₂ O ₅	SO ₃
328	6.21	61.35	7.74	.93	20.06	.64	2.56		2.50	.05	.26	.13

- 325. Roadside shale, 4 miles northwest from Dillsburg.
- 326. Clay. Philadelphia Clay Co., Toland.
- 327. Roadside shale, 2 miles north of Carlisle.
- 328. Shale quarry, 6 miles north of Carlisle.
- 329. Residual clay, Carlisle.

Selected references to the geology of Cumberland County:

- Frazer, P., Report of progress in the counties of York, Adams, Cumberland and Franklin: Pennsylvania Second Geol. Survey, Report CC, 1877.
- Hopkins, T. C., Pennsylvania State College: Annual Report for 1899-1900, appendix 1901 (description of the Mt. Holly region).
- Leighton, H., The White Clays of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. 112, 1934.
- Ries, H., High-grade clays of the eastern United States: U. S. Geol. Survey, Bull. 708, 1922 (pp. 83-89 describe the Cumberland County white clays).
- Stose, G. W., White clays of South Mountain, Pa.: U. S. Geol. Survey, Bull. 315, 1907, p. 322.

DAUPHIN COUNTY

Dauphin County lies southeast of the center of the State with Susquehanna River as its western boundary. Harrisburg, the State Capitol, is its chief city.

The county lies within three physiographic divisions. The northern half is in the Ridge and Valley section and is crossed by six sharp-crested sandstone mountains; the quarter south of the mountain section is in the Great Valley section; the southern quarter is in the Triassic Lowland section of the Piedmont province.

Ridge and Valley section.—The Ridge and Valley area of the county extends from Mahantango Creek on the north border to the southernmost high ridge, Blue, First or Kittatinny Mountain. The strata are folded into a series of anticlines and synclines. The Pocono sandstone forms the higher ridges and the Middle Devonian shales and Mauch Chunk shales underlie the valleys. From north to south the structure is as follows:

1. A syncline with Mahantango Mountain and Berry Mountain forming the enclosing ridges. Catskill red beds lie on the north side of Mahantango Mountain along the north border of the county. Here are red sandstones and shales, some of the shales being non-sandy and of fair quality for brick making. In the syncline is a wide area of Mauch Chunk red shales, exposed on the Susquehanna River at Millersburg and east through Berrysburg, Loyaltown, and Williams-town. These shales are mostly soft and could be developed at Millersburg or east along the Pennsylvania Railroad.

2. An anticline bounded on north and south by Berry and Peters Mountains and with a wide central lowland of Catskill red beds and Middle Devonian sandstones and shales. The red beds are in greater part soft red shales suitable for brick. They underlie Clarks Ferry and Halifax along the river and pass eastward along Powell Creek and Armstrong Creek.

3. Cove Mountain syncline between Peters and Second Mountains, enclosing another large area of Mauch Chunk shales from Dauphin eastward, separated into two valleys, Clarks Creek and Stony Creek, by Third Mountain. Mauch Chunk shales could be utilized at or north of Dauphin or along the Reading Railway to the east.

4. South of Second Mountain the strata continue to rise steeply, exposing narrow bands of Catskill, Middle Devonian and Middle Silurian sandstones and shales along Fishing Creek. Some of these are of good quality. To the south lies Kittatinny (First, Blue)

Mountain formed of Silurian sandstone, the southern ridge of the Ridge and Valley section.

Appalachian Valley.—South of Kittatinny Mountain there is a wide belt of lowland underlain by Ordovician and Cambrian strata. Along the Susquehanna River this belt extends from Rockville south through Harrisburg to Steelton. The northern portion of it, through Harrisburg, Union Deposit, Shellville, Grantville, and Linglestown is underlain by the Martinsburg shales. These shales are less metamorphosed than farther east and many of them are suitable for brick manufacture.

The Glen-Gery Shale Brick Corporation has been using these shales for brick manufacture in Harrisburg since 1926. This plant, one of five operated by the Glen-Gery Corporation, takes brown, thin-bedded, weathered Martinsburg shale from a large area next to the plant. Before working in a pit, it is necessary to strip two feet of loam and top soil and three feet of terrace gravel. The pits are rarely more than 20 feet deep. Light blasting blows the shale down and two steam shovels load it onto trucks which carry it 200 to 500 feet to a primary jaw crusher. This product is stored in a large bin and removed, as needed, by a modern system of conveyor belts to two dry pans which reduce most of the shale to —10 mesh. This product moves directly to the pug mill, thence to a molding machine, and a wire cutting machine that cuts the mold into brick sizes. A "soft mud" machine also makes brick by pressing the clay into sanded wooden molds. The bricks are dried for 36 hours and baked for 5 days. There are 10 driers and 10 kilns of the downdraft type. Five of the kilns are beehive and five have been made from a large continuous kiln. The kilns have an average capacity of about 60,000 brick and are in almost continuous operation. Face and building brick of varying size, color, and texture are made at the plant. Recent installation of a system of bins makes it possible to work the entire year despite bad weather.

Alluvial clay along Susquehanna River was used for making common brick at Speeceville, $3\frac{1}{2}$ miles west of Dauphin. This plant was begun in 1908 by Anthony Speece and two other men. Clay was dug from numerous pits on the flat adjoining the plant, operations being moved "when gravel became too thick." The brick were burned in five kilns, four of the Dutch kiln type, one of the beehive type. Jones Reese, of Steelton, last operated the plant about 1925. The plant has been torn down.

The southern portion of the Appalachian Valley is underlain by limestones. This belt includes Hummelstown and Hershey. Small

pockets of residual clay may accompany these limestones. These clays are plastic and red burning and may be used in small brick plants.

Triassic Lowland.—The southern part of the county from Highspire to Conewago Creek is underlain by red Triassic shales and sandstones, intruded by dikes and sheets of diabase. Near the diabase intrusions the shales are baked into a hard rock not suitable for brick making, and north of Middletown much of the Triassic is conglomeratic. In the rest of the area, however, there is much good soft red shale which makes excellent brick, especially when weathered.

At Royalton across Swatara Creek from Middletown, the Royalton Face Brick Company used weathered Triassic shale for making building brick. In 1940 the Glen-Gery Shale Brick Corp. is operating the plant. Shale is dug with an electric shovel. The operation of the plant and the product are practically the same as at the corporation's plant in Harrisburg. The plant has five beehive kilns and a daily capacity of about 42,000 brick.

Summarizing the resources of the county, it is evident that the sources of brick shales are the shale areas of the Ordovician, Middle Silurian, Middle Devonian, Catskill, Mauch Chunk, and Triassic belts; and clay occurs in the alluvial material along the Susquehanna. Two plants now operate, one in Ordovician shales, one in Triassic shales.

Selected references to the geology of Dauphin County:

Stose, G. W., and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pennsylvania: U. S. Geol. Survey, Bull. 840, 1933.

Willard, B., Swartz, F. M., and Cleaves, A. B., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

Willard, B., and Cleaves, A. B., A Paleozoic section in south-central Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 8, 1938.

Willard, B., Highway geology, Philadelphia to Pittsburgh: Pennsylvania Topog. and Geol. Survey, Bull. G 12, 1939.

Willard, B., Guide to the geology from Dauphin to Sunbury: Pennsylvania Topog. and Geol. Survey, Bull. G 13, 1939.

DELAWARE COUNTY

Delaware County is in the southeast corner of the State. Its surface is low and rolling, a part of the Piedmont province with a narrow fringe of terrace sands and gravels along the Delaware River.

The underlying rocks of the county are pre-Cambrian schists, gneisses, and gabbros. These are accompanied by stony residual soils, but seldom by usable residual clays. Pegmatite dikes are present south of Brandywine Summit and west of Elam. A large production of feldspar was obtained from these in past years. No mention is made of kaolin deposits with these pegmatites but some may be present.

Most of the terrace deposits along the Delaware River are sands and gravels but clay from the Bryn Mawr terrace 1 mile southeast of Elam was at one time used in brick making. Alluvial and terrace clays might be used in brick making along the Delaware River, but the better clays of the Tertiary and Cretaceous of the Coastal Plain lie on the New Jersey side of the river. Two brickyards now operate on surface clays in the county, the Philadelphia Brick Company at Sharon Hill and the Price Brick Company in Upper Chichester Township.

The Philadelphia Brick Company plant is located at Sharon Hill at the northeast corner of Delaware County. The company owns a large tract of clay 14 to 16 feet deep, free from sand and gravel so that grinding and sieving are not necessary. The clay is passed through a Chambers stiff mud machine, dried in a steam drier, and burned in five up-draft, coal-fired Dutch kilns, each holding 250,000 brick. The product is dark red common and face brick. The capacity of the plant is 75,000 brick a day.

The Price Brick Company makes common red building brick from clay dug at the brickyard about one mile west of Chester at Feltonville. Five kilns of 250,000 capacity each are fired with oil.

The O. K. Ketcham Terra Cotta Works at Crum Lynne, two miles northeast of Chester, makes architectural terra cotta and special roofing tile, using clay from Maryland, New Jersey, and western Pennsylvania. The product is burned in four muffle kilns averaging 24 feet inside diameter.

The geology of Delaware County is given in:

Bascom, F. et al., U. S. Geol. Survey Geol. Atlas, Philadelphia folio (no. 162), 1909.

Bascom, F., and Stose, G. W., U. S. Geol. Survey Geol. Atlas, Coatesville-West Chester folio (no. 223), 1932.

ELK COUNTY

Elk County lies north of Jefferson and Clearfield Counties and south of McKean County. It is drained chiefly by the Clarion River and its branches; Bennett Branch drains the southeastern portion. The county is in the northern plateau upland of the State and its surface is made up of wooded mountainous areas of sandstones alternating with synclinal areas of coal-bearing strata from which large amounts of coal are mined.

Four such synclinal coal basins cross the county in a northeast-southwest direction. These are: (1) the Weedville-Benezette basin paralleling Bennett Branch; (2) a wide basin from Shawmut and Brockport through Kersey and St. Marys; (3) from Lake City, through Ridgway, Johnsonburg, and Instanter; (4) a small basin in the northwest through Spring Creek and Highland. Between these basins the areas are generally forested uplands of Pottsville sandstone.

The strata that crop out in the county include, roughly:

Feet	
250	Allegheny group
300	Pottsville series
45	Mauch Chunk shales
625	Pocono shales and sandstones
100	Upper Devonian shales

The Upper Devonian (Catskill red beds) crops out only along several of the stream valleys in the southeastern portion of the county, near Dents Run. The Pocono shales and sandstone constitute the lower walls of most of the streams in the county, such as Bennett Branch and Clarion River. The remainder of the county shows Pottsville strata or Allegheny group depending on whether or not the area lies in the synclinal or the anticlinal areas.

The southeastern townships are traversed by Bennett Branch, along which the Pennsylvania Railroad and the Buffalo and Susquehanna Railroad operate. At stream and rail level the exposed rocks are of Mississippian age with the Catskill red beds appearing near the Cameron County line. The Catskill shales and some of the more shaly portions of the Mississippian might be used in brick making but no tests were made and little of value seen.

At the top of the Mississippian shales and sandstones is a thin bed of Mauch Chunk red shale. This might also be used in brick making but no good outcrops were noted. Above these and appearing only slightly above rail level in many places is the Pottsville series, consisting of heavy sandstones, some shales, and a group of thin coals, clays and shales known as the Alton coals and probably the equivalent of the Mercer group. The thin fire clays accompanying these

coals may be of value as refractories and some of the intervening shale might be used in brick making.

Above the Pottsville the shales and coals of the Allegheny group appear, usually some distance above rail level or up the side ravines one or two miles. The lowest of the coals is the Clermont, probably equivalent to Clarion or Brookville. Above it lies the Lower Kittanning coal, the principal coal mined in the valley. Both of these coals have plastic fire clays beneath them and are accompanied by brown shales suitable for brick making.

On Bennett Branch in a railroad cut just east of Weedville the following section is exposed:

Feet	
—	Coal
5	Gray clay (no. 253)
6	Buff shale
6	Concealed
2	Thin brown shale with iron concretions
75	Cross-bedded sandstone

The clay sample (253) showed fair plasticity and low green strength. It fired cream to gray with a firing range 1200° to 1300° C. It fused at cone 28 (1615° C or 2939° F). It is suited to the manufacture of fire brick. Although no detailed correlations have been made, this coal and clay are probably the Clermont (Clarion or Brookville). Just east of this outcrop about three-tenths of a mile this coal is exposed in an old mine and the clay noted below it.

North of Weedville 1.2 miles in the Byrnedale district the Lower Kittanning coal is mined where it has a thickness of about 40 inches. Beneath it is a plastic clay from 2 to 5 feet thick. Sample 247 of this clay shows good plasticity and low green strength. It fires salmon to gray with a firing range of 900° to 1000° C, swelling above 1000° C. It fuses at cone 18 and is therefore not a true fire clay. It could, however, be used in face brick manufacture.

At Caledonia thin sandstones and colored shales are exposed. These are apparently Lower Pottsville strata. To the south on the Clearfield Pike, Pottsville strata are exposed for about a mile, then the road cuts into brown shales and thin coals of the Allegheny group. Similar conditions are seen along Caledonia Run with the Allegheny coals appearing perhaps 2 miles up stream.

One mile west of Benezette and 2 miles up Spring Run, clay was taken from an old mine under a 2-foot coal. This clay was a sandy fire clay with root impressions and about 2 feet of it was exposed. The sample (244) showed fairly good plasticity and low green strength. It fired salmon to gray with a firing range of 1000° to 1200° C. It fused at cone 28. It is suited to the manufacture of face brick and fire brick.

In Benezette Township, there are high areas with Pottsville and lower Allegheny strata. In this area a clay sample (245) taken from the Fredrickson coal mine proved to be an excellent fire clay that fused at cone 32. There are other excellent fire clays in this area (see Cameron County). It seems likely that areas of the flint clay may lie on the Elk County side of the line in this district. In former days excellent fire brick were made at Benezette and Medix Run, probably from lower Kittanning clay. This fact and the tests indicate that plastic fire clays are associated with the Mercer (Alton), Brookville (Clermont), or Lower Kittanning coals along Bennett Branch. These clays lie from a few feet to 200 feet above rail level and can be reached by short inclines or trams one or two miles long.

The Brockport-St. Marys basin of Allegheny coals and clays includes the well known coal-mining areas of Brockport, Shawmut, Elbon, Dagus, Kersey, and St. Marys. Lower Kittanning (B or Dagus) is the chief coal mined, but near St. Marys, Clermont (Clarion or Brookville) coal also is mined. No tests were made on the plastic clays underlying these coals but with the successful use of Lower Kittanning clay at Brockway, southwest of Brockport, in sewer pipe manufacture, the use of plastic clays at Shawmut in paving brick manufacture, and the very extensive use of the same clay at Mt. Marys in sewer pipe manufacture, it is evident that the Allegheny clays of the basin have excellent possibilities. The Erie and the Pittsburgh, Shawmut and Northern Railroads serve the area.

Three large plants are operating at St. Marys.

The North American Refractories Co. has a plant one mile west on Route 120. Hard flint and soft plastic clay are mined underground on Knights Hill about two miles south of the plant. The clay is hauled to the plant on a tram road. Dry-press and hand-molded fire brick and shapes are burned in 10 down-draft rectangular kilns. The company also sells fire clay dust in bulk and in 100-lb. bags. The company's plant at Dagusahonda is partly dismantled.

On the east side of the borough along Route 120 are the plants of the Saint Marys Sewer Pipe Company and Saint Marys Clay Products Company. Both are under one management, use local clay and shale, and make the same products, sewer pipe, drain tile, flue lining, etc. The Sewer Pipe Company has 30 coal-fired, round, down-draft kilns, and the Clay Products Company 24.

Along the Clarion River from Millstone on the west to Ridgway and Johnsonburg and north, Mississippian shales interbedded with shaly sandstones and sandstones are to be seen in many outcrops. Good thick pure shale layers are not common and the use of shales requires much sorting. They have been used at Ridgway and at Johnsonburg in the manufacture of red brick. Just south of John-

sonburg the Yingling-Martin Brick Company formerly made red brick, operating a shale bank at three levels. The shales of the upper level were carried to the plant by cable, those of the middle terrace by incline, and the lower shales by rail under the highway. The lower portion of the quarry shows:

	Feet
Sandstone	5
Nodular sandstone with pyrite	5
Dark shale (sample 161)	10
Sandstone	10
Fossiliferous shale	4
Hard fossiliferous sandstone	6
Dark shale like No. 161	15

Sample 161 showed fair plasticity and low green strength. It fired to a light red to brown and overburned suddenly at 1200° C. It is suited to the manufacture of face brick and drain tile. Much of this type of shale was seen from Johnsonburg to Ridgway. A sample (428) taken along the road north of Ridgway shows a plasticity rating of 70 and a linear drying shrinkage of 5 percent. It fires to a brown color and develops a volume burning shrinkage of 18 percent at cone 7. It fuses at cone 15. It is a lean sandy shale capable of making a low grade brick.

Little is known of the clay possibilities of the northwestern section of the county. The higher hills carry small areas of the Allegheny group and it is in such areas that the better clays and shales are to be expected.

Physical tests of Elk County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point (cone)	Best burning range (cones)	Firing color	Suggested uses
161	19.25	3.32	5	83	2.82	4	13	—	Light red to brown	Face brick, drain tile
244	22.9	4.0	3.5	88	5.60	9	28	07-4	Salmon to gray	Face brick, fire brick
245	21.2	3.7	7	72	5.10	9	32	02-9	Cream to gray	Fire brick
247	25.5	4.1	8	28	7.60	02	18	010-07	Salmon to gray	Face brick
253	22.5	4.3	5	65	6.50	6	28	4-9	Cream to gray	Fire brick

Chemical analysis of Elk County clay

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
161	4.67	66.46	8.58	.53	13.36	.62	—	—	—	.01	—	—

- 161. Shale. Yingling-Martin Brick Co., Johnsonburg.
- 244. Fire clay, one mile west of Benezette.
- 245. Fire clay. Frederickson coal mine, Benezette Township.
- 247. Plastic clay, 1.2 mile north of Meadville.
- 253. Clay. Railroad cut east of Woodville.

Selected references to the geology of Elk County:

- Ashburner, C. A., The township geology of Elk, Cameron and Forest counties: Pennsylvania Second Geol. Survey, vol. R 2, pt. II, 1885.
- Ashburner, C. A., Atlas for Elk, Cameron and Forest counties: Pennsylvania Second Geological Survey, R 2, Atlas, 1884.
- Sisler, J. D., Bituminous Coal Fields of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 6, Pt. 2, 1926, pp. 194-197.

ERIE COUNTY

Erie County is in the extreme northwestern corner of the State bordering on Lake Erie. Erie, the principal city, is an important manufacturing and fishing center in the midst of a great fruit-growing area. The country is traversed by the main line of the New York Central Railroad, the Erie Railroad and by branches of the Pennsylvania Railroad.

Topographically the county can be divided into three zones: The lake plains, the "escarpment", and the plateau upland. The lake plains form a belt along Lake Erie ranging from two to five miles wide. They represent the silt-covered bottoms and shore lines of earlier glacial lakes. Their surface is made up of sands and sandy clays deposited by the lake waters. Beneath lie soft shales which are exposed along the present lake cliffs and in the deeper stream valleys. The lake plains rise to 150 feet above the present lake level (573 feet) or 600 to 725 feet above sea level.

The "escarpment" is a more or less continuous gentle slope rising from the lake plains to the levels of the plateau area. Down its slopes the main streams flowing into Lake Erie have cut deep and picturesque gullies or "gulfs" through the morainic clays and the underlying shales and sandstones.

The southern half of the county is the plateau area, a fairly level or slightly rolling upland rising to heights of 1700 to 1800 feet above sea in the southeastern corner of the county. The upland area is covered with glacial drift; rock exposures are few.

The northern half of the county drains into Lake Erie through a series of short streams which head on the plateau. The southern half of the county drains through French Creek and other streams, into the Allegheny River system. The bedrock of the county consists of flat-lying sedimentary strata, chiefly shales and thin sandstones.

These beds dip gently to the south or southwest, the dip rarely exceeding 20 feet per mile. The exposed beds range from the Shumla sandstone 475 feet down in the Portage division of the Devonian system, up to the Shenango sandstone near the top of the Mississippian system, a total vertical range or thickness of about 1700 feet. The general section is as follows:

Feet

20	Shenango sandstone.
65	Meadville shales, gray, sandy, with a thin limestone, the Meadville.
65	Sharpville sandstone, with a thin lower Meadville limestone.
75	Orangeville shale, bluish, weathering brown; many iron nodules.
20	Corry sandstone.
1	Cussewago limestone.
30	Shales and flagstones.
25	Cussewago sandstone.
80	Riceville shales, bluish, sandy.
320	Venango oil sand group; sandstone, conglomerate and shales.
325	Chemung shale and sandstone; much flagstone.
225	Girard shales, soft blue and gray.
475	Portage shale, with thin sandstone bands.

The Portage shales border the lake and are exposed in the lake cliffs. The Girard shales underlie the upper bench of the lowlands and are exposed in the lower courses of many of the streams. The Chemung beds are more resistant and make the "escarpment"; they are uncovered in its deep gullies. The higher strata underlie the uplands and rarely are well exposed.

The shales that underlie the lake plains have been utilized for brick making at two points in the county. The only brick yard in the county at present is that of the Dunn Brick Works at 1644 East 12th Street in Erie, or about two miles east of the heart of the city. The shale is obtained from a large pit in the flat lowlands and has been taken out in two 16-foot benches. The upper weathered material is the better but this has largely been removed. The very smooth soft blue shale now used is represented by sample 424. It has a plasticity rating of 80 and a linear drying shrinkage of 4 percent. It burns red to brown at cones 1 to 9 with volume shrinkage 7.2 to 15 percent and absorption 4 to 14.2 percent. It fuses at cone 16 (1463°C). It is suited to the manufacture of face brick and tile. They manufacture common brick, mingled ranges of matt texture face brick and hollow building tile.

The shale is dug with steam shovels and trammed to the plant. It is then passed through jaw crusher and dry pan and screened with an electric screen, the tailings being returned to a pulverizer. The clay then passes through a Sturtevant pug mill and brick machine and is cut with Chambers cutter. The brick are dried in waste

heat dryers and burned in 5 round kilns. One continuous kiln and a periodic one have also been used but are now idle. Coal is used for firing. Although the brick have a rather close firing range, by careful firing a very good red face brick is made.

Some years ago the Glenwood Brick Company operated a brickyard in the Glenwood district in the southern part of the city of Erie, using Girard shale said by local brick men to have been of high quality. This plant has been dismantled with the development of that section for residential purposes.

The Girard shales are exposed in many of the streams in the lowlands and one exposure on Walnut Creek at Route 20 was sampled (339). This locality is about nine miles west of Erie. Along Walnut Creek there are fine exposures of this ash-colored shale free from sandstone layers and in available thicknesses of 25 feet or more. The tests show that the shale has good plasticity and fires to a salmon to brown color. Its firing range, however, is short, only from 1100° to 1150° C. It has a maximum linear firing shrinkage of 6.4 percent at 1150° C, and above that temperature suddenly begins to swell and deform. It fuses at cone 12 (1370° C).

The use of the Girard and Portage shales and these tests would indicate that they can be successfully made into good face brick but they must be selected and burned carefully. No doubt mixtures of the shales with some of the glacial clays would add to their value but the short firing range probably would still give trouble. These shales lie along the main rail lines and are thus easily accessible.

The Chemung shales on the "escarpment" to the south are less valuable for brick making as they are interlaminated with thin sandstone beds that would be difficult to separate. The shales of the Venango, Riceville, Orangeville and Meadville series lie in the southern uplands and are not well exposed. They are generally sandy and of no great value but their former use at Corry in brick making indicates that some of these shales might be used in making red face brick or even paving brick. The plant of the Corry Brick and Tile Company is one mile west of Corry on a switch from the Erie Railroad. The plant has been idle for some years but formerly made red face brick and paving brick. In their quarry there is exposed 20 feet of sandstone carrying "*Spirifer*" *disjunctus* in abundance. Below is 15 feet of dark shale, sample 388. The tests show that the shale has good plasticity and burns to a salmon to dark brown color. It has a firing range from 1150° to 1250° C and a maximum (linear) firing shrinkage of 8 percent at 1150° C, which slowly decreases as the temperature is raised. It is apparently suited to the manufacture of red brick and tile. At least it is an indication that some shales in the upper series might be used.

There is thus in Erie County but one active brick yard, the Dunn Brick Works at Erie. Two others, one at Erie and one at Corry, have operated in the past. Much shale is available but most of it is too sandy or has a short burning range.

The chief description of the geology of Erie County is Pennsylvania Second Geological Survey Report Q4, by I. C. White, published in 1881.

Physical tests of Erie County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point (cone)	Best burning range (cones)	Firing color	Suggested uses
339	22.6	2.9	6	90	6.4	1	12	03-1	Salmon to brown	Red brick and tile Face brick and tile
388	25.0	4.4	6	181	8.0	1	15	1-6	Salmon to dark brown	
424		4.0				7	16	1-7	Red to brown	

Sample 424 had a plasticity rating of 80 and reached a maximum burning shrinkage of 15 percent at cone 7.

339. Shale, 9 miles west of Erie.
 388. Shale, 1 mile west of Corry.
 424. Shale, Dunn Brick Works, Erie.

FOREST COUNTY

Forest County is a small one in the northwest part of the State. It lies east of Venango and north of Clarion County. It is in the main a high, forested plateau deeply dissected by the Allegheny and Clarion rivers and Tionesta Creek. The strata are practically horizontal and range from the lower part of the Allegheny group, through the Pottsville series, and into the Mississippian beds. The Allegheny beds occur only in the higher knobs of Jenks Township and include a thin Clarion coal. In these beds there is a possibility of fire clay or good brick shales but none are now known.

The main upland strata are the Pottsville sandstone and conglomerate. Little clay or shale accompanies these sandstones but where the Mercer or Sharon coals (the old Alton and Marshburg coals) occur one might expect fire clays or shales of value. None, however, were encountered.

Along the main river valleys the exposed strata consist of thin sandstones, sandy shales, and soft clay shales of the Mississippian period. Among these are to be found bluish or olive-colored shales suited to the manufacture of red brick, and similar in quality to shales (386 and 387) tested in Warren County.

Such shales are accessible along the Allegheny River on Route 62 from East Hickory south to Tionesta and east from that city along Tionesta Creek to Nebraska. The best of these shales seems to lie about 5½ miles east of Tionesta, near Nebraska. If brick were to be made in the county the Tionesta area would seem to be the most likely.

The most detailed information and geologic maps of Forest County are contained in report R 2 of the Second Geological Survey of Pennsylvania by C. A. Ashburner, being the report on the township geology of Cameron, Elk, and Forest counties, with atlas in separate volume. They appeared in 1884 and 1885.

FRANKLIN COUNTY

Franklin County is in the middle of the southern tier and borders on Maryland. Its western border is Cove and Tuscarora Mountains, the most eastern of the sandstone ridges of the folded Appalachian or Ridge and Valley province. With a few subordinate ridges of this Medina or Tuscarora quartzite, these mountains overlook the Great Valley which occupies most of the county, a flat fertile belt of limestone and shale of Cambrian and Ordovician age. On the eastern border of the county South Mountain rises, a great mass of crystallines, igneous and metamorphic, of pre-Cambrian age.

The clay and shale resources are confined to the Clinton shale, the upper Ordovician (Martinsburg) shales and to residual clays forming through the decay of the Ordovician and Cambrian limestones and shaly quartzites.

The Clinton shales are gray and pinkish, with some sandstone. They average 750 feet in thickness and occur on the flanks of the mountains of Tuscarora quartzite in the western part of the county in two areas; 1, Horse Valley north of Fort Loudon and 2, Little Cove south of Cove Gap. Both areas are somewhat isolated and it is not likely the shales will be used although tests made in other counties usually show that they are of brick making quality.

The Martinsburg shale of upper Ordovician age is about 1,500 feet thick and the lower half is much the purer, being a dark, blocky shale weathering in places to a lighter colored clay. It forms a wide

outcrop from north to south through the central line of the county, its eastern edge being on a line from Greencastle to Chambersburg and north. Between Chambersburg and St. Thomas it forms a solid belt and farther west three bands of its alternate with the lower limestones up to the western mountains. Sample 301 was taken on the highway 1 mile east of St. Thomas, the outcrop extending 100 feet along the road. Its plasticity and green strength were fair. It burned salmon to good brick red with a burning range of 1050° C to 1150° C. From it could be made brick, hollow tile or drain tile. Much of the Martinsburg shale seems as good or better than this sample and it would seem that much good brick-making shale may be obtained.

The limestones of the Ordovician form the fine agricultural valley land in a north-south belt east from Chambersburg to the South Mountain area. They are exposed also in the coves between the mountains in the western part of the county. Deep decay has given rise to yellow and red residual clays on this limestone. These are very plastic and could be used in making brick or tile and some types of stoneware. No tests were made on them.

Some of the residual clays are white, especially those derived from the Chickies quartzite and the Antietam sandstone. These occur on the flanks of the South Mountain in some of the old iron ore pits. Such white clays have been reported from Black Gap, Mont Alto, Tomstown, and near Chambersburg. Clay from near Chambersburg was used by the Penn Tile Works Company at Aspers in making vitrified tile. Clays of similar origin have been worked commercially in Cumberland, York, and Lancaster Counties.

Building brick have not been made in Franklin County in many years. A row of brick houses in the eastern part of Chambersburg, called Wanamaker Row, was built of hand-made brick shortly after the Civil War. Probably local residual clay derived from limestone was used.

Selected references to the geology of Franklin County:

Frazer, P., Report of Progress in the counties of York, Adams, Cumberland and Franklin: Pennsylvania Second Geol. Survey, Report CC, 1887.

Stose, G. W., U. S. Geological Survey Geol. Atlas, Mercersburg-Chambersburg folio (no. 170), 1909.

Tests on sample 301 included in tables of tests for Adams County.

FULTON COUNTY

Fulton County lies east of Bedford County and is bordered on the south by Maryland. It is within the folded Appalachian province and is made up of a series of mountain ridges and intervening valleys trending east of north. Rays Hill and Sideling Hill are on or near the western boundary and Tuscarora Mountain forms much of the eastern boundary. Between these lie less prominent ridges and wide, rolling valleys. The Lincoln Highway crosses the county through McConnellsburg, Harrisonville, and Saluvia, and the Pennsylvania Turnpike near Burnt Cabins, Fort Littleton, and Hiram.

The exposed rocks within the county are shales, sandstones, and limestones ranging from Ordovician age, as around McConnellsburg, to Pennsylvanian age in the Broad Top coal field.

The eastern border of the county is made up of a belt of Ordovician strata about four miles in width, McConnellsburg being in an anticlinal valley in the center of the belt. In this valley north and south through McConnellsburg reddish residual clays overlie Beekmantown limestone. These clays have been used in brick making locally and in other counties, but were not tested in Fulton County. About $1\frac{1}{2}$ miles east of McConnellsburg, on the flank of Tuscarora Mountain, the Martinsburg (upper Ordovician) shale is exposed as a series of olive, blocky shales. These are represented by sample 302, taken at the sharp curve on the Lincoln Highway. The test shows that the shale has good plasticity and fair green strength. It fires to a salmon to dark red-brown with a firing range from 1150° C to 1200° C. It is suited for the manufacture of hollow tile and drain tile. This shale forms a belt about 18 miles long on the west slope of Tuscarora and Cove Mountains, and a similar belt along the west side of McConnells Cove, as seen two miles west of McConnellsburg along the highway. These belts of Martinsburg shales are evidently the best source of brick materials in the eastern part of the county.

North and south through the central part of the county is a wide belt of Devonian strata. In the northern and southern ends of this zone the Lower Devonian strata, including the Oriskany sandstone, are exposed. In Huntingdon County to the north, this sandstone has weathered into a siliceous white clay which is used as a fire brick cement and has other possibilities. (See Huntingdon County.) Pockets of such clay may accompany the Oriskany beds in Fulton County but none have as yet been uncovered.

The remaining and largest area of Devonian is underlain by olive gray shales and sandstones of the Middle Devonian (Chemung to Hamilton age) flanked by much red shale of Catskill age. The gray shales appear around Burnt Cabins on the north and extend down

through Harrisonville on the Lincoln Highway and on south. They are similar to the gray Devonian shales in Bedford County that tests show are of good quality for brick making. The red and olive shales were sampled at Paterson Run, one mile east of Harrisonville as sample 303. The plasticity and green strength were good. It burned salmon to dark red-brown with a firing range from 1050° C to 1200° C. It could be used in making brick, hollow tile, or drain tile. These red shales are to be seen from a point three miles west of McConnellsburg, through Saluvia and on to Sideling Hill, where Pocono sandstones appear. Brick could be made at many localities in this central Devonian area.

Catskill red shales are abundant in the western part of the county, and Mauch Chunk red shales occur between Sideling Hill and Rays Hill; also south and east of Broad Top Mountain. The softer shales of these formations could be of use in brick making but the area is somewhat sparsely settled. The small area of Pennsylvanian in the northwest corner is the southeastern edge of the Broad Top coal field but carries no known clays or shales of value.

Common brick were made at the north end of McConnellsburg by Peter Morton from about 1902 to 1910. Residual clay from limestone was used. This is said to have been the only custom brickyard in the county. The Court House is of brick reported to have been burned from clay dug on the spot. At present no use is made of any of the shales or clays of the county, but it is evident that the Devonian and Martinsburg shales could be manufactured into red brick and tile and that the red residual valley clays in McConnells Cove might also be made into red brick products.

Physical tests of Fulton County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point at cone	Best burning range (cones)	Firing color	Suggested uses
302	27.7	3.3	7	103	8.8	4	15	1-4	Salmon to dark red brown	Brick, hollow tile, drain tile, and drain tile
303	20.2	4.4	13	144	4.8	02	15	05-4	Salmon to dark red brown	

Chemical analyses of Fulton County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
302	5.73	62.37	8.69	.92	13.64	.25	2.40	.97	1.08	.05	.30	1.81
303	5.26	57.28	7.80	.06	22.58	.97	1.65	.33	.29	.02	.31	1.02

302. Martinsburg shale, $1\frac{1}{2}$ miles east of McConnellsburg.
303. Devonian shale, 1 mile east of Harrisonville.

Selected references to the geology of Fulton County:

Gardner, James H., The Broad Top Coal Field of Huntingdon, Bedford and Fulton Counties: Pennsylvania Topog. and Geol. Survey, Rpt. 10, 1913.

Stevenson, J. J., The Geology of Bedford and Fulton Counties: Pennsylvania Second Geol. Survey, vol. T 2, 1882.

Stose, George W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (no. 170), 1909.

HUNTINGDON COUNTY

Huntingdon County lies south of the center of the State, north of Bedford and Fulton counties and east of Blair County. It is in the zone of the folded Appalachian Mountains whose ridges and valleys here trend east of north. The strata exposed within the county range from upper Cambrian to middle Pennsylvanian. Hard quartzites form the sharp ridges; the valleys are chiefly underlain by shales and limestones. The Juniata River and its branches cross the county as do also the main line of the Pennsylvania Railroad and the William Penn highway. The Broad Top and Huntingdon Railroad and the East Broad Top Railroad serve the southern half of the county.

The northwestern townships between Bald Eagle and Tussey Mountains are a portion of the Nittany Valley, a fertile anticlinal valley underlain chiefly by Cambrian and Ordovician limestones. Deep weathering of this area has produced a residual soil ranging from a few feet to a hundred feet thick. Much of this soil is colored plastic or sandy clays. These are very irregular and pockety, depending on the underlying structure and the character of the rock from which they have formed. Among these clays are pockets of white clay, usually siliceous derived from the Gatesburg formation, which is predominantly dolomite but contains much quartzite. On account of their irregularity these clays must be prospected and worked with caution. They are frequently associated with residual limonite ores, formerly worked. The colored, mottled clays have little value although they could be used in brick manufacture and in the production of various art pottery. Clays that approach a light gray to white color have value as refractories, sagger clays, and perhaps as china or paper clays. Up to the present they have been used only as a silica cement in setting fire brick and in sagger manufacture. The chief difficulty in their use in china manufacture or as a paper filler

seems to be the very fine character of the associated silica which makes complete washing very difficult.

White clay from Gatesburg formation

The Gatesburg formation underlies a large area northeast of Birmingham. Much of the area is wooded and the surface is covered with sand and quartzite fragments so that the finding of clay pockets is difficult. They have usually been found through the search in former days for iron ore. Other masses of good white clay may yet be discovered. The known deposits in this quadrangle will be described in order beginning at the north.

Microscopic examination reveals that the white clays are true kaolins made up largely of kaolinite plates ranging between .001 and .016 millimeters in size. There is also much of the characteristic kaolinite fan and "worm" shaped material which is usually about .010 by .020 millimeters.

In general, it may be said that the whiter grades of the clay are plastic, burning to a cream to a lighter buff color. Their linear air shrinkage averages around 14 percent, the volume air shrinkage about 5 percent. The maximum fire shrinkage is reached between 1350°C (cone 11) and 1430°C (cone 15). They fuse between 1615°C (cone 28) and 1650° (cone 30).

Dungarvin.—There are several old clay and ore pits near Dungarvin station on the Scotia branch of the Pennsylvania Railroad. Pits were opened some years ago under the name of J. T. Throop but in recent years they have been controlled by the Everett-Saxton Company of Philadelphia and worked under lease by William Lykens, R. D. 1, Warriorsmark. The main pits are just northwest of the station. They cover an area of 600 by 1200 feet and have an average depth of 25 feet. Exposures now show picturesque cliffs and pinacles of every hue, and furnish a fine example of the irregular, pockety nature of these residual clays. The discontinuance of railroad service in 1927 put a stop to the working of the clay. During World War I Mr. Lykens also took clay from pits south of the railroad.

The clay property owned by Miss Mary Patton of Hollidaysburg lies 0.7 of a mile northwest of Dungarvin and was formerly connected with the Scotia branch of the railroad by a short tram when iron ore was mined. In more recent years prospecting has been carried on for white clays by the West Virginia Pulp and Paper Company and by East Liverpool chinaware interests. Large but irregular pockets of white clay have been encountered under a cover of 5 to 20 feet. One body of clay was 33 feet thick. The clay was said to carry 30 to

40 percent fine silica but this could be readily washed out. The companies demanded a washed product and the irregular nature of the occurrence probably worked against any large outlay of capital for such a washing plant so that the pits are now idle. Two well-constructed circular shafts 20 feet in diameter are filled with water; also an old open pit. No very good sample can now be obtained.

Pennington.—A clay pit lies half a mile east of Eyer station or 1 mile southwest of Pennington station on the Scotia branch of the Pennsylvania Railroad. It is owned by C. J. McCauley, Second National Bank Building, Altoona, and was worked by William Lykens, R. D. 1, Warriorsmark. This operation has been idle several years. The old loading tipple is 1000 feet east of Eyer and the pit 1000 feet southeast of the tipple. The pit shows an overburden of 10 feet of yellow soil carrying small fragments of chert and iron ore. This is underlain by from 5 to 15 feet of plastic white, gray or mottled clay. After the railroad discontinued service, the clay, dug by hand, hoisted by derrick and gas engine was trucked 2 miles to a shipping point at Stover. The clay was shipped to steel mills to be used as a cement.

Shoenberger.—A pit $2\frac{1}{2}$ miles northeast of Shoenberger and $2\frac{1}{2}$ miles east of Birmingham is at the site of the old Dorsey iron ore pits. It was operated by Harry Eckenrode in 1936 for Egan & Webster, Grant Building, Pittsburgh. The pit shows 10 to 15 feet of white clay and gray clay under yellow soil, ore, and chert. In 1940 it was operated by the Acme Clay Company, Frick Building, Pittsburgh. The clay is hauled by truck to the main line of the Pennsylvania Railroad at Shoenberger, and shipped to steel mills for use as a refractory cement and lining.

White clay from Oriskany formation

The Oriskany sandstone crops out nearer the center of the syncline. It enters from Bedford County as a narrow belt, broadening north of McConnellstown into the Warrior Ridge area between Petersburg and Huntingdon. Thence the outcrop swings east in a curve and then south as a narrow upturned sandstone to Mapleton and beyond.

The Shriver siliceous dolomite and chert lying just under the heavy sandstone of the Oriskany weathers in many places to a white or gray siliceous clay resembling that from the Gatesburg formation. These clays are dug near Alexandria and Shirleysburg.

Alexandria.—The Alexandria Fire Clay Company, under the direction of G. I. Phillips, operates a white clay pit three miles southeast of Alexandria, along the old Philadelphia Pike across Warrior

Ridge. The pit has a high west wall of the upper Oriskany sandstone dipping steeply west; a central zone of white clay carrying chert and some shale and dipping steeply beneath the heavy sandstone. The zone of mineable material is about 50 feet wide. The east wall is shale representing the lower Oriskany. It is not weathered to clay and is not used. The material mined is a fine-grained, white to gray, siliceous clay carrying impressions of trilobites and brachiopods, an unusual feature in residual clays.

The clay is dug with power shovel and milled in a plant at the pit. The plant has a rotary dryer, and KV hammer mill for crushing the clay, chert, and shale. The milled product is trucked to loading bins on the Pennsylvania Railroad $1\frac{1}{4}$ miles south of Alexandria. A valve-bag sacker at the silos is used for packaging. The clay is shipped to steel mills and coke ovens, and is used as mortar in laying refractory brick, mostly in open hearth practice.

This clay was first dug by Sam Hatfield about 1870 for use in a local iron furnace; later it was shipped by way of the Pennsylvania Canal to Barree Furnace. Shaw¹ says this is a siliceous clay with good burning properties; satisfactory as cement in laying silica brick but not to be used as a refractory where basic ash or slag is encountered.

Petersburg.—Red and black clay in the Oriskany formation was dug years ago in the hill north of Petersburg, and in recent years white clay on the hillside southeast of the village was produced by C. R. Reeder.

Shirleysburg.—This property was formerly known as the Rock Hill Clay Co. but in 1930 it was purchased by Harbison-Walker Refractories Co. and is now known as the Walker mine. The pit is located $1\frac{1}{2}$ miles southeast of Shirleysburg, in Huntingdon County. It was formerly connected with the East Broad Top Railroad by a tram but now haulage is by truck to a loading station at Shirleysburg. The coarse upper Oriskany sandstone crops out near by and it is apparent that the clay here is the weathered product of the lower Oriskany shales, although it may represent the Marcellus. The shaly nature has been preserved in the clay and it shows a steep west dip. The smooth blocky gray clay differs from the Alexandria clay in having no grit or chert fragments and in being darker and showing distinct shale laminations.

Operations are conducted by a few men but a steady production is maintained, the clay going to the Harbison-Walker Refractories Co. plants. In former days clay was shipped to the Atlanta Terra

¹ Shaw, J. B., Fire clays of Pennsylvania: Pennsylvania Topog. & Geol. Survey, Bull M 10, 1928.

Cotta Co. and to rubber firms. It is now used for furnaee linings, fire brick cement, and other refractory purposes. Tests made by J. B. Shaw for the Geological Survey are given below; sample 205 a white clay and 206 a blue clay although it is not practical to separate them.

	<i>Sample 205</i>	<i>Sample 206</i>
Plasticity	good	good
Green strength	high	high
Fired color	light buff brown	light cream to dark buff
Burning range	1100° to 1250°C.	
Water of plasticity	39.8%	60.5%
Shrinkage water	11.2%	13.8%
Pore water	28.7%	46.7%
Volume air shrinkage	14.2%	20.8%
Linear air shrinkage	4.5%	6.5%
Fusion	Cone 27	Cone 27
Maximum linear fire shrinkage	12.3%	14.2%
Maximum shrinkage reached at ...	1350°C.	1300°C.

Other pockets of such clays are to be expected within the Oriskany area but none are now open.

Shales

The central part of the county between Tussey Mountain on the west and Jacks Mountain on the east is a wide synclinal area. The two ridges are of Silurian quartzites, and between them lies, in turn, Clinton shales, Helderberg limestone, Oriskany sandstone, Middle Devonian shales, Catskill red shales, Pocono sandstone, Mauch Chunk red shales, Pottsville sandstones, and some of the Pennsylvanian coal measures. The Mississippian and Pennsylvanian strata lie in the center of the syncline in southern Huntingdon County, and represent the northern extension of the Broad Top coal field and plateau. In the central part of the county along Juniata River and to the north, the strata are Devonian or Upper Silurian.

The Silurian shales include the Wills Creek, the Bloomsburg red shales, and the Clinton green and purple shales. They form a broad belt east of Tussey Mountain through Marklesburg, Alexandria, and Neffs Mills across the northern townships, and south in a narrow belt on the west flank of Jacks Mountain. No tests have been made on these within the county but shales capable of making common brick doubtless are present.

Farther within the synclinal area there is a broad belt of Middle Devonian shales around Huntingdon and Mill Creek. The Huntingdon and Broad Top Mountain RR. follows these shales south from Mount Union to Orbisonia. From location and quality they seem

the most promising shales of the county. Tests were made on them as follows:

Sample 307 is a shale, probably of Marcellus age, cropping out along the highway near the railroad 0.7 mile south of Mill Creek. It shows good plasticity and green strength and fires to a salmon to red-brown color. It has a burning range from 1050° to 1150°C. It seems suited to the manufacture of face brick, hollow tile or drain tile.

Sample 308 is a buff shale, probably of Hamilton age, on Route 76, 0.7 mile north of Mill Creek. It has fair plasticity but low green strength, fires to a salmon to red-brown color with a burning range of 1100° to 1200°C, and is rated as a fair shale for brick making.

Sample 309 is an iron-stained sandy shale (Hamilton age), one mile north of Mill Creek on Route 76. It has fair plasticity and green strength and fires to a salmon to red-brown color with a burning range of 1100° to 1200°C. It is a fair brick shale.

Sample 310 is from a fine exposure of lower Hamilton shales on the Huntingdon and Broad Top Mountain Railroad in the southwestern part of Huntingdon. This shale has fairly good plasticity, low green strength, fires light brick red to red-brown, with a burning range of 1100° to 1150°C, and is a fair shale for brick making.

Sample 314 is a Middle Devonian smooth, blocky, olive-green shale from the roadside southeast of Orbisonia, on Route 522, 0.7 mile south of Black Log Station. This is in the Devonian shale belt traversed by the East Broad Top Railroad south from Mt. Union. Tests show good plasticity and low green strength. It burns to a pink to red-brown with a good burning range of 1100° to 1150°C, and is a fair brick shale.

These tests of five mid-Devonian shales indicate that this area traversed by the Pennsylvania Railroad and the Broad Top Railroad contains shales capable of making face brick, common brick, and hollow and drain tile, and that they are easily accessible by rail or highway.

The Catskill red shales and sandstones appear along the Juniata River between Mill Creek and the mouth of Raystown Branch. Thence the outcrop extends in two bands to the south, one on each side of Broad Top Mountain. The western outcrop is traversed by Raystown Branch and the eastern by Smith Run. No tests were made on these shales but their use at Saxton in Bedford County indicates that excellent brick can be made from them.

The Pocono sandstone of Mississippian age borders Broad Top Mountain on the south-central part of the county as a double ridge, Terrace Mountain on the west and Sideling Hill on the east. Within this synclinal rim lie wide areas of Mauch Chunk red shale with brick making possibilities. Within the circle of these shales lies the Pottsville sandstone belt and upon and within it the shales and coals of the Broad Top coal field. These coals have been largely worked out and there seems to be no record of fire clays of value with them. The accompanying shales could probably be burned into red brick.

Summarizing the clay resources of the county it is to be seen that the two important sources are the residual white refractory clays of the Nittany Valley and of the Oriskany area, and the Devonian shales of the central and eastern parts of the county. The white clays are mined extensively and shipped to steel mills; the shales are not utilized.

Location of samples tested from Huntingdon County.

204. Washed clay. Dorsey ore pit. Land of Edna Zentmyer. Warriors-mark township.
 205. Clay with Oriskany sandstone. Shirleysburg.
 206. Blue clay. Same pit as 205. Shirleysburg.
 207. Clay from McCullough pit, Pennington.
 208. Clay from McCullough pit, Pennington.
 209. Clay from same pit as 204. Dorsey pit.
 210. Clay from same pit as 204. Dorsey pit.
 307. Shale (Marcellus?) 0.7 mile south of Mill Creek.
 308. Shale (Hamilton?) 0.7 mile north of Mill Creek.
 309. Shale (Hamilton?) 1 mile north of Mill Creek.
 310. Shale (Hamilton) on Huntingdon and Broad Top Mountain Railroad, Huntingdon.
 314. Shale (Devonian) 0.7 mile south of Black Log Station.
 421. Clay from pit 2½ miles northeast of Shoenberger. Dorsey ore pit.
 A White clay. Alexandria Fire Clay Company. 3 miles southeast of Alexandria (from Bull. M 10).

Physical tests of Huntingdon County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of staking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point at cone	Best burning range (cones)	Firing color	Suggested uses
204	37.7	3.5			4.1	11	26	02-9	Pure white	Refractories, white ware and paper
205	39.8	4.5			12.3	11	27	02-6	Light buff	Pottery, tile, low grade refractory
206	60.5	6.5			14.2	9	27		Cream to buff	Tile and low grade refractory
207	21.7	5.6	5	59			29	05-11		Refractories
208	18.3	4.1	5	63	1.1	4	30	05-11	Buff	Refractories
209	22.4	3.8	7	41	9.3	9	28	05-11	Buff	Refractories
210	30.4	5.7	9		10.1	9	27	4-9	White to gray	Refractories
307	19.3	3.3	5	144	5.7	1	15	05-1	Salmon to red-brown	Face brick, hollow tile, drain tile
308	19.1	1.8	6½	90	5.3	4	14	02-4	Salmon to red-brown	Fair clay for brick
309	21.7	4.6	8	113	5.7	02	14	02-4	Salmon to red-brown	Fair clay for brick
310	17.8	2.1	4	99	5.9	02	12	02-1	Light red to red-brown	Fair clay for brick
314	26.3	4.3	6	98	7.6	1	13	02-1	Pink to red-brown	Brick
421		8.5			11.5	6	29		Cream white	Refractories, pottery and paints
A	29.9	4.6	6		4	11	28		Cream white	Silica cement

Chemical analyses of Huntingdon County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
308	3.94	66.82	10.38	.73	20.57	.85	2.50	1.55	.78	.02	.65	.27
309	4.46	60.49	8.56	.76	20.98	.64	1.42	1.81	.86	.01	.01	.20
310	5.17	58.45	10.58	.96	18.26	.86	2.16	1.93	.86	.33	.06	.52
314	5.70	61.25	12.37	.60	14.99	.44	.24	1.42	.267	.03	.20	.95

Selected references to the geology of Huntingdon County:

Butts, C., Swartz, F. M., and Willard, B., The geology of the Tyrone Quadrangle: Pennsylvania Topog. & Geol. Survey, Atlas 96, 1939.

Butts, Charles, Geologic section of Blair and Huntingdon counties, central Pennsylvania: Amer. Jour. of Science, 4th. ser, v. 46, pp. 523-537, 1918.

Leighton, Henry, White clays of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. 112, 1934.

White, I. C., The Geology of Huntingdon County: Pennsylvania Second Geol. Survey, Report T3, 1885.

JEFFERSON COUNTY

Jefferson County lies east of Clarion and Armstrong counties and north of Indiana County. It is bounded on the north by the deep and rugged valley of the Clarion River and on the northeast by Toby Creek with similar characteristics. Redbank Creek and its tributaries, Mill Creek and Sandy Liek Creek, flow across the middle of the county and drain the greater part of it. Mahoning Creek crosses the southern part. The interstream areas rise to heights of 1500 to 1800 feet above sea level and perhaps average about 1600 feet in elevation. The major streams flow in valleys 400 to 500 feet below the plateau uplands. The uplands are gently rolling in the central and southern parts and rugged and wooded in the northern townships. The northern section is without railroads, the central section is served by the Pennsylvania, New York Central, Pittsburg and Shawmut railroads; the eastern area by the Erie; Buffalo, Rochester and Pittsburgh; and the Pittsburg, Shawmut and Northern Railroads; the southern border by the Buffalo, Rochester and Pittsburgh and a branch of the Pennsylvania Railroad, and Summerville by the Lake Erie, Franklin & Clarion RR. The abundance of railroads along the stream valleys is due to the intensive coal mining.

The rocks of the county are all sedimentary and are but slightly folded. They include strata from those of the Pocono series of Mississippian age seen along the Clarion River, up through the Pottsville and Allegheny groups, and including about 250 feet of the lower Conemaugh group. Under the influence of a strong antiline, some

Pottsville and much Allegheny strata are brought up in the extreme southeastern corner of the county; a synclinal structure results in a wide belt of Conemaugh strata extending northeast through Punxsutawney, Big Run, and Sykesville, and on through Du Bois; west of this belt the surface is chiefly of Allegheny beds with Pottsville rocks appearing along some of the valleys and in a wider area on the plateau of the northern townships.

Punxsutawney District

The greater part of the Punxsutawney district in the southeastern portion of the county is underlain by Conemaugh strata which, as said, lie in a synclinal belt passing through Punxsutawney and northeast through Sykesville. The Conemaugh section displayed extends up to about the horizon of the Ames limestone so that the strata seen are those of the lower Conemaugh, chiefly of the Brush Creek and Mahoning horizons. Massive sandstones are few, the prevailing rock being dark shale. At Punxsutawney much shale of the Brush Creek section is present and brick and tile could no doubt be made with little difficulty. At Williams station on the Buffalo, Rochester and Pittsburgh railroad 2 miles east of Punxsutawney Ashley* measured a section as follows:

	Ft.	in.
Sandstone	6	
Dark shale		6
Black shale		1
Olive shale	2	
Colored shales	4	
Very ferruginous limestone	4	
Olive shale	23	
Black shale		1
Olive drab clay	3	5
Shale grading into sandstone	10	

These shales and the clay should make a good mixture for brick unless too high in lime.

In the vicinity of Sykesville many exposures of the Brush Creek shales are to be seen. At the railroad station a cut shows 10 feet of sandstone, 10 feet concealed, probably shale, and at the bottom 20 inches of Brush Creek limestone. A quarry west from this has a section showing

	Ft.
Thin black shales	20
Brush Creek limestone	1
Shale	3
Brush Creek limestone	2
Dark shale	3
Mahoning sandstone	10

* Ashley, G. H., Geology and mineral resources of the Punxsutawney quadrangle: Pennsylvania Topog. and Geol. Survey, Atlas 65, p. 25, 1926.

Half a mile north of the station at Sykesville the Hydraulic-Press Brick Company operates a brick yard and makes a variety of colors of face brick under the trade name "Hytex", using a shale quarried across the road from the plant. It is a buff shale overlain by 10 feet of buff sandstone and underlain by 15 feet of thin-splitting, black, iron-stained shale. The strata probably are just above the Brush Creek limestone horizon. The buff shale (no. 259) has fairly good plasticity and a fair green strength. It fires to a red to brown color with a firing range from cone 08 to cone 01. It is well suited to the manufacture of face brick or hollow tile. The shale is ground in a dry pan, moulded in an auger machine and burned in a battery of 7 round down-draft kilns. This plant is an excellent example of the use which can be made of the Conemaugh shales of this district.

East and southeast of Big Run is an area in which are exposed all the Allegheny group and in Clover Run, some of the Pottsville series. The only coal that has been mined here is the Upper Freeport. It is usually underlain by clay but the clay appears to be thin and often sandy. The other coals are not worked but it would be well to remember that the Lower Kittanning coal may have a good clay below it and also that within 25 to 50 feet below the Brookville coal flint clays might be expected, although none have been reported from that area.

South from Canoe Creek along Canoe Creek and Ugly Run there are exposures of the Lower and Upper Freeport coals and the Upper Freeport coal is mined. The underclays as a rule are too thin to work. Ashley* reports 3½ feet of clay under the Upper Freeport opposite the mouth of Ugly Run. This might be worth prospecting.

North and northwest of Punxsutawney the Allegheny strata again appear up Sawmill Run and Elk Run around Walston and Adrian. Here the Upper and the Lower Freeport coals have been mined extensively. The floors of these coals generally are in clay but as far as known none of the clay has been mined. Ashley¹ states that in the Walston district the clay below the Lower Freeport coal is 3 to 4 feet thick in several mines.

Southwestern District

West from Walston and Adrian and south of Little Sandy Creek is an area comprising the southwestern townships of the county. In the southwestern portion of this district some of the higher land carries the Mahoning strata of the Conemaugh group. They form the greater part of the surface in Porter Township. The valleys are cut mainly in rocks of the Allegheny group. These include Mahoning Creek on the south, Hamilton Run, Nye Branch, Pine Run, Big Run, and Little Sandy Creek. The railroads of the district include the

¹ Ashley, G. H.: loc. cit. p. 74.

* Ashley, G. H.: loc. cit. p. 74.

Buffalo, Rochester, and Pittsburgh along Mahoning Creek, and the Pittsburgh, Shawmut and Northern along Pine Run and northeast through Markton. Shales are abundant in the areas of Conemaugh strata on the highlands and there are plenty of good shales in the Allegheny group. None of these have been used for brick making. The Allegheny coals are usually accompanied with underclays of some value although none of these have been utilized. The Lower Freeport coal is mined at Horatio and Valier along the Mahoning valley and is underlain with clay. At Frostburg, according to Platt,² potter's clay from under the Lower Freeport coal was used at a pottery, this pottery later changing to a clay from under the Upper Freeport limestone near Perry Church.

The deep valley of Pine Run exposes the Allegheny group down to strata below the Vanport limestone. Along the Pittsburgh and Shawmut Railroad near Timblin the Lower Kittanning coal is mined as well as the Upper Freeport. Clays should be available along this railroad, especially under the Lower Kittanning coal.

Along Big Run from the Perry Township line north to 1 mile below Sprankle Mills the Vanport limestone is brought above stream level and the strata of the lower Allegheny and the upper Pottsville are exposed. Platt* mentions a hard fire clay below the Brookville coal near Sprankle Mills and it seems probable that clays of value will be found at this horizon or in the upper beds of the Pottsville. The Shawmut Railroad near Sprankle Mills offers transportation for any industry established there. The Shawmut Railroad from this point crosses a divide which carries it above the horizon of the Vanport limestone. It then descends into the valley of Little Sandy Creek where the lower Allegheny and the upper Pottsville beds are exposed from Oliveburg down stream almost to Worthville. Here a syncline carries them below stream level but just west of Worthville they reappear and continue to the mouth of the stream. Since valuable flint clays are found under the Brookville coal and in the Mereer horizon at Brookville and east from there to Reynoldsville, Little Sandy Creek valley is promising territory for exploration. The Lower Kittanning coal and clay should appear about 50 feet above the Vanport limestone; the Clarion beds 50 feet below it; and the Brookville coal and clay 80 feet below the Vanport limestone.

No clay or shale is now being utilized in this southwestern section of the county.

² Platt, W. G.: Pa. Second Geol. Survey, Report. H6, p. 16.

* Platt, W. G.: loc. cit. p. 55.

Brookville District

The Brookville district includes the area north from Little Sandy Creek in west central part of the county within a radius of approximately 8 miles from Brookville. It is drained chiefly by Redbank Creek flowing southwest from Brookville in a deep valley; by Sandy Lick Creek and Mill Creek coming into Brookville from the east; and by the North Fork of Redbank Creek flowing in from the north. The Pennsylvania Railroad follows Redbank and Sandy Lick creeks across the district. The Pittsburgh and Shawmut Railroad follows Mill Creek and goes south from Brookville. Branches of the New York Central enter the western portion. There are no railroads north of Brookville in the county.

Brookville is situated where North Fork and Sandy Lick Creek join in Redbank Creek. The town is built on the beds of Pottsville sandstones which here consist of the Homewood sandstone, a heavy-bedded rock about 55 feet thick; the Mercer beds made up of dark shales, thin coals and clays; and a lower series of sandstones, the Connoquenessing, which are finer grained and less massive than the overlying Homewood beds. The hills around the city and in its higher parts carry the lower portions of the Allegheny group including the Lower Kittanning coal, the Vanport limestone, and the Clarion and Brookville horizons.

In the east end of Brookville or at Port Barnett, the Humphrey Brick and Tile Co. manufactures face brick, using shale and clay that probably belong in the Mercer horizon. There seems to be a question whether the upper sandstone is the Clarion or the Homewood. The section at their new quarry and beds below the quarry shown by drill holes are given in the following sections:

<i>Quarry</i>	<i>Ft. in.</i>		<i>Drill hole</i>	<i>Ft. in.</i>	
Sandstone	15		Clay	2	
Coal	2		Coal	2	6
Clay, in drift	8		Soft clay	1	6
Concealed	5		Coal		10
Shale used	20		Clay	13	
Coal	1	6	Coal	1	
Soft clay	3		Slate		10
Dark shale	3		Coal	2	1
Coal	1		Clay	1	7
Clay (no. 289)	8		Coal		6
			Clay	1	9
			Dark clay	2	4
			Dark shale		4
			Dark clay		5
			Sandstone	7	10
			Flint clay	3	7
			Sandstone	1	5

The presence of so much elay in a section is unusual. Of most interest is the presenee of the flint clay which may be in the Mereer horizon. If the beds in the quarry are of Brookville age then the lower flint clay may be Mereer. Similar flint elay crops out on an adjoining part of the property of the company along the road just east of the plant, and sample 290 represents surfaee samples of it. This clay fired to a cream color with a firing range from cone 06 to cone 13 and fused at cone 32½. It is good grade of flint clay suitable for the manufacture of refractories. Sample 289, the elay from the quarry, has good plasticity and a fair green strength. It burns salmon to brownish-gray with a firing range from cone 06 to cone 01. It fuses at cone 17. It is not a fire elay but is suited to the manufacture of face brick. The company now uses mostly the upper shale but this elay could be mixed with the shale for different effects. The plant is equipped with rolls and dry pans and two Bonnat auger maehines. The brick are burned with a battery of 17 round, gas-fired kilns.

Samples 393 and 394 represent flint elay taken from the O'Neil mine on Swamp Run, just south of Brookville. These are from the Mereer horizon or above and were collected by Mr. C. K. Graeber of the Survey staff. Sample 393 fired to a white to cream color and sample 394 to a gray. No. 393 fused at cone 29 and no. 394 at cone 33. Both have a firing range from cone 3 to cone 13. They are flint elays of good grade and are suited to the manufacture of various refractories. F. B. Hetrick, owner of the property, states that the elay lies 12 feet below the Brookville coal and ranges from 4 to 11 feet thiek. The clay is trueked to the railroad and shipped to various points. Graeber measured the following section. He places the elay in the Mercer group.

	Ft.	in.
Coal		4
Clay	1	
Sandstone	10	
Semi-flint clay	1+	
Dark flint clay		2 to 1 foot
Light flint clay	3 to 6 ft.	
Sandstone	2+	

Platt¹ gives interesting details regarding Mereer fire clays formerly worked several miles east of Brookville along Sandy Lick Creek, at Bellport and vicinity. The following notes have been taken from his description. The section of the Pottsville in that vicinity shows

¹ Platt, W. G.: loc. cit. pp. 156-158.

	Ft.	in.
Homewood sandstone	50	
Slate	5	
Upper Mercer coal	2	4
Clay	3	
Concealed	55	
Sandstone	20	
Coal, irregular		3
Fire clay	0-11	
Sandstone	25	
Impure clay	5	
Sandstone	50	

The two sandstones below the fire clay are Upper Connoquenessing. The clay between them seems too impure for shipment. The main clay lies immediately upon the Connoquenessing sandstone in pot-like cavities varying in thickness from zero to 11 feet. This clay was mined at that time at various localities but the chief mine was that of Brown & Erskine at Bellport. The clay varied in quality and at one exposure showed:

	Ft.	in.
Sandy clay	3	
Soft clay	1	6
Hard clay	3	
Soft clay	1	6

The analysis of the clay (the best hard clay) showed SiO_2 44.22 per cent and Al_2O_3 38.15 percent. It was apparently a good grade of flint.

The flint clays in the area just east of Brookville indicate that there is a bed or beds of flint clay between the Brookville coal and the Connoquenessing sandstone in the area which will bear further study or prospecting. Similar flint clays are known both east and west of Reynoldsville and it seems likely that there is an area of such clays in the intervening district.

South from Brookville between Fivemile Run on the east and Red-bank Creek on the west is an area underlain by Allegheny strata. The Brookville coal is mined at Conifer and the Middle and Lower Kittanning near Knoxdale. The Upper Freeport coal is mined at Ramsaytown and Knoxdale. This is also correlated by some with the Lower Freeport. Clays accompanying these coals are not developed. That good clays occur is shown by tests made on a sample from the roadside just south of Stanton. This clay about 3 feet thick is evidently a Freeport or a Kittanning clay. The sample (294) has good plasticity and a fair green strength. It fires to a cream to gray color and has a firing range from cone 06 to 01. It

fuses at cone 20 to 26. It is best suited to the manufacture of buff face brick or sewer pipe. Probably the best clay in the area is the clay that underlies the Brookville coal. This has already been noted at the Humphrey plant at Brookville. In former years a pottery was operated by Newsome, Porter and Co. south from Brookville at the top of the hill above the railroad tunnel. This locality is described by Platt¹ and analyses are given of the Brookville clay used. The section shown in the area is as follows:

	Ft.	in.
Clarion coal	2	
Clay	4	
Sandstone and shale	30	
Brookville coal	1½-5	
Shale	6	
Coal		6
Clay	6-11	
Homewood sandstone		

Mr. Graeber in a letter states that in his correlation the Brookville coal above should be Clarion.

At the pottery about 6 feet of the Brookville clay was used and it is stated that the material was somewhat sandy. It seems, however, that this horizon between the Clarion coal and extending down into the Pottsville sandstone is the most promising section for clays. No flint clays are reported below the Brookville horizon but they are to be expected. Fivemile Run flows over upper Pottsville rocks and in its banks and along the Shawmut Railroad which follows it clays would be expected. Redbank Creek southwest from Brookville flows in a deep valley of Pottsville strata with the Brookville, Clarion, and Lower Kittanning horizons higher up on the banks and in the side valleys. Brookville and Lower Kittanning coals are mined at Coder, Summerville, and at other points along the New York Central. At Summerville the Hanley Ceramics Co. has an exceptionally well equipped plant for the manufacture of buff face brick, frit-glaze brick, and other products. The plant is equipped with jaw crushers, Hanley dry pans, two Hanley auger machines, a Boyd press and 2-way tunnel kilns fired with gas. The clay used is mined about half a mile up a small stream north of the plant. Lower Kittanning clay is mined in Mine No. 3. It consists of about 3½ feet of plastic clay underlain by 10 feet of harder inferior clay. Sample 291 represents the better portion. This has a fairly good plasticity and fair green strength. It burns cream to speckled gray with a burning range from cone 04 to cone 9, and fuses at cone 26. It seems suited to the manufacture

¹ Platt, W. G.: Report of progress in Jefferson County. Second Penna. Geol. Survey, pp. 104-105, 1881.

of face brick, sewer pipe, or low-grade refractories. Lower Clarion clay is mined in Mines Nos. 1 and 2. The average section shown is as follows:

	Ft.	in.
Lower Clarion coal	2	2
Plastic clay	7	
Shales	18	
Brookville coal	3	
Clay	2	
Shales	—	

This clay has practically the same properties as the Lower Kittanning and the two are mixed in the plant. Samples 391 and 72 and 73 also represent the clays used at the Hanley plant. Their fusion points run from cone 20 to cone 28.

Three miles northwest of Summerville at Sutton, in Clarion County just west of the Jefferson County line, a cut along the New York Central Railroad shows a section of the Clarion beds as follows:

	Ft.	in.
Upper Clarion coal	1	
Clay	3	
Brown shale	12	
Lower Clarion coal	2	6
Clay (no. 297)	7	

This clay has good plasticity and fair green strength. It burns cream to gray with a firing range from cone 06 to 9 and fuses at cone 27. It seems suitable for the manufacture of fire brick, sewer pipe, or face brick.

West from Brookville the main highway toward Clarion follows uplands which are made up largely of the upper Allegheny strata. Shales are abundant and in the lower sections the clays below the Lower Kittanning and the Clarion and Brookville coals would be expected. At Corsica on the line between Clarion and Jefferson counties the DeHaven Coal Co. mines the Lower Kittanning coal by the stripping method. Above the coal is from 10 to 15 feet of brown shale (no. 295) which is removed. This shale has fairly good plasticity and a fair green strength. It burns to a red to brown color with a burning range from cone 08 to cone 04. It is suitable for face brick manufacture. Below the coal lies a bed of plastic clay. The upper portion, which was sampled as no. 296, is light gray and free from siliceous material. It is from 2 to 3½ feet thick. The lower portion is more siliceous and is about 3 feet thick. The good clay has fair plasticity and green strength. It fires to light to dark gray with a firing range from cone 06 to 13, and fuses at cone 32. It is evidently an excellent fire clay and could be used for refractories.

This property has a rail spur into it and it would seem that the shale and clay could be developed easily, or that other similar deposits could be opened in the western part of the county. North from the Brookville-Corsica road the Allegheny group forms the surface rock for 4 or 5 miles, beyond which the lower Pottsville beds become the dominant stratum of the northern townships.

North and northeast from Brookville the Pottsville strata crop out along the major streams such as the North Fork and Mill Creek, and the higher divides are in Allegheny beds. Little is known about the clays of this region. Brown shales of good quality occur between Brookville and Sigel and clay blossoms were noted near Howe.

Reynoldsville District

Reynoldsville lies along Sandy Lick Creek, 12 miles east of Brookville. It is served by the Pennsylvania Railroad. The city is built upon Allegheny strata, the Lower Kittanning coal being at the lower levels. The hills to the east and southeast are capped with Conemaugh beds, while Sandy Lick Creek valley to the west cuts down into the Pottsville series. The district has long been an important coal-mining center with the Lower Freeport coal as the principal producer.

The Hydraulic-Press Brick Co. operated a brick yard at Reynoldsville manufacturing face brick and other products until about 1938. A 6-foot bed of Lower Kittanning clay (no. 288) was mined in the hill south of the plant, which is three-quarters of a mile southwest of Reynoldsville on Sandy Lick Creek and the Pennsylvania Railroad. The section as seen near the plant is as follows:

	Ft.	in.
Coal	1	
Shale and sandstone	15	
Shale	8	
Coal, Lower Kittanning	1	6
Clay (no. 288)	6	
Brown sandstone	6	
Ferruginous sandstone	1	
Blue, limy shales	3	
Sandstone	4	6
Iron nodules, Vanport fossils	6	
Concealed, slight show of coal and clay	61	

The clay has good plasticity and fair green strength. It burns buff to speckled gray with a burning range from cone 04 to cone 3 and it fuses at cone 26. It is well adapted to face brick manufacture.

West along Sandy Lick Creek no clays of importance are known until Meredith is reached. At Meredith the Kane Brick & Tile Co.

has made red face brick from a shale quarried $1\frac{1}{2}$ miles north. The section at the pit is as follows:

	Ft.	in.
Coal and wash	4	
Shale (no. 287)	12	
Coal		9
Sandstone	8	

The exact horizon of this shale is not known but it lies in the middle of the Allegheny group. The shale has fair plasticity and low green strength. It burns red to brown with a burning range from cone 08 to cone 04. It is adapted to the manufacture of face brick or tile. The shale is carried down to the plant by tram road, and molded in a Freese machine after grinding in a Stevenson dry pan. The brick are burned in 7 kilns using as fuel Brookville coal mined on the south side of the creek. The Harbison-Walker Refractories Co. formerly mined flint clay from what is known as the "Old Meredith Mine" on the south side of the creek at Meredith. This mine is about 60 feet above the stream and is probably in part of the Mercer formation. The clay bed averages about 6 feet thick and is overlain and underlain by massive sandstones. The flint clay (no. 286) burns to a cream color with a firing range from cone 06 to cone 13. It fuses at cone 33. It is a high-grade flint clay. Prospecting has been done by other firms in the Meredith region but the results are not known. It would seem, however, that between Meredith and Brookville the Mercer horizon should be carefully tested. The high hills north and south of Sandy Lick Creek are capped with the Freeport coals but little is known of the clay resources.

The hills east of Reynoldsville carry the upper part of the Allegheny group and some of the higher hills have some of the lower Conemaugh. Soldier Run and other valleys are in the lower part of the Allegheny group. Just east of Prescottville clay and its overlying coal are exposed. These belong to M. Kochik who has mined the coal. The coal is $1\frac{1}{2}$ feet thick and the underlying grey clay 6 feet. The clay (no. 257) has good plasticity and green strength. It burns buff to gray and fuses at cone 20. However, it has poor burning properties and Shaw thinks it to be of doubtful value. It may be one of the Kittanning clays.

Falls Creek and Brockway Districts

On Sandy Lick Creek from Reynoldsville to Falls Creek the exposed rocks are all of the upper part of the Allegheny group. At Pancoast, $1\frac{1}{2}$ miles west of Falls Creek, an interesting clay occurs at the Goss lime plant, on the land of the Reynoldsville Lime Co.

The Lower Freeport coal here is about 8 feet thick. Under it is a few feet of shale, followed by a fresh-water limestone 2 to 9 feet thick. Directly under this, or with an interval of a few feet of shale, there appears a 4-foot bed of flint clay of good quality. This is irregular in thickness and in proportion of flint and plastic clay. The flint as now exposed is represented by samples 256 and 285. Both are typical flint clays with low plasticity and green strength. They burn cream color with a burning range from cone 06 to cone 13. One fused at cone 31 and the other at cone 28. If the correlations are correct this gives a new horizon for flint clay, under the Lower Freeport limestone. The property is on the Pennsylvania Railroad and is easily accessible. The clay has not been worked although both the coal and the limestone have been used.

About a mile east of Pancoast, along the Pennsylvania Railroad, is the brick plant of the Hydraulic-Press Brick Co. The shale used comes from a quarry on the north side of the road, the material being carried to the plant by tram road. The section in the quarry is as follows:

	Ft.	in.
Buff shale	10	
Coaly streak, little coal	3	
Sandstone	6	
Dark papery shale with orbiculoidea, etc.	12	
Persistent sandstone bed	0	9
Gray-brown papery shales	17	
Coal, good	1	
Gray clay	1	
Gray, sandy shale	3	

Use is made of the various shales and some surface soil is included. No sample was taken from the quarry but the mixture makes a very good grade of face brick. Falls Creek lies in Pottsville rocks and the belt of Pottsville continues up Wolf Run along the eastern border of the county. Half a mile north of Falls Creek on the Buffalo, Rochester & Pittsburgh Railroad the following section, evidently in the Mercer group, is exposed in a cut.

	Ft.	in.
Coal, poor	2	
Clay, sandy at base	3	6
Good clay	1	
Blue shale	5	

The 4½ feet of clay were sampled as no. 255. The plasticity is good and the green strength low. The clay burned to buff to gray with a burning range from cone 3 to cone 9. It fused at cone 29. It seems suited to the manufacture of fire brick.

Beyond Harveys Run the Pottsville strata give way to Allegheny beds; shales above the Vanport limestone are seen. Between McMinns and Lanes Mills the Vanport horizon is exposed and 20 feet below it the Clarion coal with 2 to 3 feet of yellowish under clay. The following sections are exposed north of McMinns and just north of Lanes Mills Station and on the hill to the west:

<i>McMinns</i>		<i>Lanes Mills</i>	
	Ft. in.		Ft. in.
Black shale	10	Coal, Upper Freeport .	—
Vanport limestone	3	Concealed	2
Concealed	20	Limestone	3
Clarion coal	2 6	Concealed	10
Yellow sandy clay	3	Sandstone	5
Shale and sandstone ..	15	Shale	2
		Coal, Lower Freeport (?)	3 4
		Clay (no. 254)	2
		Concealed to railroad ..	35

This clay, perhaps the Lower Freeport, has good plasticity and green strength. It burns buff, light brown, to gray with a burning range very short. It fuses at cone 14 and is not thought to be of value. Just west of Brockway, The Brockway Clay Co. operates a large plant, making sewer pipe, flue lining, and wall coping, from local clay and shale. The product is burned in 26 round, down-draft kilns.

Northern Townships

The northern townships are underlain by Pottsville strata. An occasional high knob is capped by some of the Clarion and Brookville beds. Coal has been mined in this area from the Mercer horizon but no mention is made of Mercer clays of value. The Clarion River cuts deeply into the Pottsville and into the underlying Mississippian strata but nothing of value in the way of clays is to be expected below the Mercer horizon. Although no clays have been reported, flint or plastic clays might be expected under the Brookville coal and thence down into the Mercer horizon. This area is largely wooded and rugged.

Localities from which Jefferson County clays tested were obtained:

- No. 72. Plastic clay, Clarion bed, lower part, Hanley Ceramics Co., Summerville.
 73. Plastic clay, Clarion bed, upper part, Hanley Ceramics Co., Summerville.
 Nos. 72 and 73 above, were tested by Shaw and described in Bull. M-10, 1928.
 254. Plastic clay, under Lower Freeport (?) coal, north of Lanes Mills.
 255. Plastic clay, on B. R. & P. R. R., $\frac{1}{2}$ mile north of Falls Creek.
 256. Flint clay, Reynoldsville Lime Co., Pancoast.

257. Plastic clay, Kochick mine, $\frac{1}{4}$ mile east of Prescottville.
 259. Shale. Hydraulic-Press Brick Co., Sykesville.
 285. Flint clay, Reynoldsville Lime Co., Pancoast.
 286. Flint clay, old Harbison-Walker mine, Meredith.
 287. Shale, Kane Brick & Tile Co., Meredith.
 238. Plastic clay, Hydraulic-Press Brick Co., Reynoldsville.
 289. Plastic clay, Clarion (?) bed, Humphrey Brick & Tile Co., Port Barnett.
 290. Flint clay, Mercer bed, Humphrey Brick & Tile Co., Port Barnett.
 291. Plastic clay, Lower Kittanning bed, Hanley Ceramics Co., Summer-ville.
 294. Plastic clay, on road near Stanton.
 295. Shale, over Lower Kittanning coal, DeHaven Coal Co., Corsica.
 296. Plastic clay, under Lower Kittanning coal, DeHaven Coal Co., Corsica.
 297. Plastic clay, Lower Clarion bed, on N. Y. Central Railroad, Sutton.
 391. Plastic clay, Lower Kittanning bed, Hanley Ceramics Co., Summer-ville.
 393-394. Flint clay, Mercer bed, O'Neil mine, Swamp Run, 2 miles south-east of Brookville.

Physical tests of Jefferson County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking, minutes	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point cone	Best burning range cones	Firing color	Suggested uses
72	22.56	9.35*	5		24.10*	9	20 $\frac{1}{2}$			
73	24.66	13.57*	9		26.57*	9	27 $\frac{1}{2}$			Building brick or tile
254	23.3	6.1	4.5	226	6.60	1	14	Short	Buff to light brown	Fire brick
255	21.8	3.9	5.5	72	5.50	9	29	1-6	Buff to gray	Doubtful value
256	18.9	2.6	4.5	87	2.43	07	28	07-11	Light cream	Fire brick
257	20.4	4.9	6	225	3.20	05	20		Buff to gray	Fire brick
259	25.2	4.7	6	160	7.80	02	12	010-02	Red to brown	Doubtful value
285	17.3	1.9	2	90	1.20	05	31	07-11	Cream	Face brick, hollow tile
286	20.9	1.6	2	9	6.10	4	33	07-11	Cream	Fire brick
287	20.7	3.0	5.5	85	4.90	6	13	010-05	Red to brown	Fire brick
288	20.2	—	9	135	4.40	02	26	05-1	Buff to gray	Drain tile, face brick
289	21.7	4.2	6	153	5.90	02	17	07-02	Salmon to gray	Face brick
290	18.9	4.2	5	—	6.90	05	32 $\frac{3}{4}$	07-11	Cream	Face brick
291	19.9	5.3	7	118	3.60	9	26	05-6	Cream to gray	Fire brick
294	23.8	4.0	7.5	180	6.60	4	26	07-02	Cream to gray	Face brick, sewer pipe
295	22.5	3.6	4	175	6.10	02	14	010-05	Red to brown	Face brick
296	20.0	3.9	3	110	4.60	02	32	07-11	Light to dark gray	Face brick
297	21.8	5.3	7	125	3.80	1	27	07-6	Cream to dark gray	Fire brick
391	23.1	4.7	7	129	5.8	11	28	1-11	White to gray	Fire brick, face brick, sewer pipe
393	21.6	4.0		35	5.9	11	29	1-11	White to cream	Face brick, fire brick
394	20.7	1.5			5.9	9	33	1-11	Gray	Refractories

* Volume shrinkage.

Chemical analyses of Jefferson County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
72	—	59.76	2.64	.19	29.30	1.08	1.50	—	—	—	—	—
256	8.31	62.40	3.39	1.61	21.10	.97	.21	—	—	.10	.02	1.45
257	7.66	63.05	4.60	Tr.	19.09	.64	.60			.01		2.42
P 1	14.68	44.22	.51	2.15	38.15*	.02	.23		.03			
P 2	9.72	58.12	3.33		26.50	.07	.55		2.18			.05
P 3	9.09	60.67	2.21		25.91	.08	.46		1.92			Tr.
P 4	4.16	78.07	1.59		14.44	.05	.48		1.67			Tr.

* By difference.

Analyses P 1-4 were described in Report H 6 of the Second Pennsylvania Geological Survey:

P 1. Hard clay, Brown and Erskine mine, Bellport Mills, 2 miles south-east of Port Barnet, Mercer clay, p. 157.

P 2-4. Clays from Brookville bed. Newsome, Porter & Co. pottery on hill just south of Brookville.

Selected references to the geology of Jefferson County:

Ashley, G. H., Geology and mineral resources of the Punxsutawney Quadrangle: Penna. Topog. & Geol. Survey Atlas 65, 1926. Describes the geology of southwestern Jefferson County.

Platt, W. G., Report of progress in Jefferson County: Second Penna. Geol. Survey, Report H 6, 1881.

Shaw, J. B., Fire clays of Pennsylvania: Penna. Topog. and Geol. Survey, Bull. M 10, 1928. Gives results of tests on samples Nos. 72 and 73.

Sisler, J. D., Bituminous coal fields of Pennsylvania, Pt. 2. Penna. Topog. & Geol. Survey, Bull. M 6, pt. 2, 1926. Pp. 35-329 deal with coals of Jefferson County.

JUNIATA COUNTY

Juniata County is south of the center of the State and borders Mifflin County on the southeast. It lies within the ridges and valleys of the Appalachian Mountains with the structures trending north-east. It is crossed from west to east by the Juniata River, which, with its tributaries, drains the county. The western border of the county is a Tuscarora sandstone ridge, Black Log and Blue Mountains, and its eastern border a similar ridge, Tuscarora Mountain. The intervening territory is a great syncline carrying much Clinton shale and most of the Devonian rocks. The Juniata River crosses the county chiefly in the Clinton shales, which are well exposed in the vicinity of Mifflintown and Thompsettown.

Clinton shales are seen one mile east of the Mifflin-Juniata county line along the Juniata River in Lewistown Narrows. Sample 318 is from these dark splintery olive-green shales along the William Penn Highway, Route 22. This shows good plasticity and fair green strength. It fires salmon to red-brown with a firing range of 1050° to 1150° C. It could be used in making brick, hollow tile, and drain tile. Thence east to Mifflintown, bluish, buff, and red Clinton shales and a few thin limy beds are exposed. Sample 317 was taken half

a mile north of Mifflintown along the highway from a bank of red and buff shale. This has good plasticity and low green strength. It fires to a good brick red with a firing range of 1000° to 1150° C. It could be used in the manufacture of red face brick.

South from Mifflin much Clinton shale is exposed along the Pennsylvania Railroad. Sample 315 taken one mile south of Mifflin represents an average of buff, red, and bluish shales. It proved of little value, having poor plasticity, a low firing range, and was too high in lime to be of much value.

One mile east of Thompsontown on U. S. Route 22 splintery, dark Clinton shales were sampled as no. 316. This showed good plasticity and fair green strength. It fired to a light brick red to red-brown with a firing range of 1050° to 1150° C. It is suitable for the manufacture of brick, hollow tile, and drain tile.

Through Mexico and expanding into a wider belt in the north-eastern corner of the county is an area of Middle Devonian shales. Some of these could no doubt be used in brick making but in general they are of lesser value than the Clinton shales and are not so accessible.

Localities from which samples were obtained:

- 315. Clinton shale, 1 mile south of Mifflin, Juniata County.
- 316. Clinton shale, 1 mile east of Thompsontown, Juniata County.
- 317. Clinton shale, $\frac{1}{2}$ mile north of Mifflintown, Juniata County.
- 318. Clinton shale, in Lewistown Narrows, Juniata County.
- 319. Clinton shale, 3 miles west of Milroy, Mifflin County.

Physical tests of the clays of Juniata and Mifflin Counties

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point at cone	Best burning range (cones)	Firing color	Suggested uses
315	16.6	2.4	5	6	None	—	10	—	Pink-buff to dark buff	None
316	17.1	5.1	5½	113	2.6	1	15	05-1	Light brick red to red-brown	Brick, hollow tile, drain tile
317	18.2	3.6	5	72	2.7	02	10	07-1	Good brick red	Face brick
318	21.3	3.8	5½	117	6.7	1	15	05-1	Salmon to red-brown	Brick, hollow tile, drain tile
319	19.6	2.5	3	73	6.6	1	14	02-1	Salmon to red-brown	Brick

Chemical analyses of Juniata and Mifflin Counties

No.	lgm	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
316	5.04	56.78	3.36	1.05	27.89	1.13	3.02	.71	.18	.10	.10	.23
317	6.34	52.34	19.77	.69	10.61	3.06	2.53	1.60	.96	.14	.69	.43
318	5.01	54.98	10.34	1.17	21.35	.64	2.42	—	—	.10	.26	.22
319	4.67	56.86	8.43	.97	20.33	.13	1.14	1.58	.09	.10	.12	.43

Reference to the geology of Juniata and Mifflin Counties:

d'Invilliers, E. V., Report on the geology of the four counties, Union, Snyder, Mifflin and Juniata: Pennsylvania Second Geol. Survey Report F 3, 1891.

Willard, Bradford, Cleaves, A. B., and Swartz, F. M., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

LACKAWANNA COUNTY

Lackawanna County lies south of Wayne County in the north-eastern plateau section of the State. It is drained by the Lackawanna River and its tributaries flowing southwestward into the North Branch of the Susquehanna River, and in the north by various small streams flowing west and north into the Susquehanna. The Delaware, Lackawanna and Western Railroad crosses the county from northeast to southwest through Scranton, the Lehigh Valley Railroad serves its southwestern border along the Susquehanna River, and other railroads lie within the industrial Lackawanna Valley area.

The county is divided by the wide, low synclinal Lackawanna Valley. This valley is bordered on the northwest by Bald Mountain, a ridge of Pocono sandstone, and on the southeast by a similar ridge known as Moosic Mountain. Within the valley is the intensive mining and industrial area, a part of the Northern Anthracite Field, including Scranton, Wilkes-Barre, Carbondale, and other cities.

The county is underlain by Pennsylvanian, Mississippian, and Upper Devonian strata, nearly horizontal in the northern and southern portion but highly tilted within the Lackawanna synclinal area.

The southern part of the county is a high plateau of sandstones and shales of Catskill age. The higher portions are generally sandstones, and streams such as Spring Brook and Roaring Brook have cut down into underlying red Catskill shales. The extreme southeastern corner is underlain by the Elk Mountain and Cherry Ridge divisions of the Catskill and the rest of the plateau up to the Pocono sandstones of Moosic Mountain is underlain by the Mount Pleasant red shales and sandstones. Within this belt there may be opportunities for the development of the softer red shales for brick making but most of the plateau is sandy. The northern portion of the county, northwest of Bald Mountain, is a similar plateau of Catskill sandstones and shales with the better shales in a belt just north of Bald Mountain extending through Clarks Summit. Most of the rocks, however, are too sandy for brick making. Within the Lackawanna Valley syncline opportunities for shale development are limited. The

rim rocks are Pocono and Pottsville sandstones. The Mauch Chunk formation, which to the southwest is made up of a very thick series of red shales, is, in this county, only 150 feet of grayish flagstones with only minor amounts of gray shale.

The center of the valley is underlain by 500 to 700 feet of highly folded Pennsylvanian shales and anthracite beds. There are no fire clays with the anthracite beds and the shales are usually too dark and carbonaceous for use or are too slaty. Experiments have shown that brick can be made from the highly carbonaceous shales by a slow burning process. At present (1940) no brick are made in the county. Peter Stiff and Son operated a brickyard in Scranton, making building brick and paving brick, but this plant has been discontinued and dismantled.

Selected references to the geology of Lackawanna County:

White, I. C., Report on Wyoming, Lackawanna, Luzerne, Columbia, Montour and Northumberland Counties: Pennsylvania Second Geol. Survey, vol. G 7, 1883.

Willard, B., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

LANCASTER COUNTY

Lancaster County has for its western boundary the Susquehanna River and its south border is the Maryland line. It is entirely within the Piedmont plateau province, divided into rolling uplands of harder rocks and low valley lands chiefly limestone. The county may be divided roughly into three east-west bands: (1) a northern belt of Triassic red shales and igneous intrusives; (2) a central one of Ordovician and Cambrian limestones and shales; (3) a southern belt of crystalline schists and igneous rocks, chiefly pre-Cambrian. Extending into the county from the east are two highland areas of pre-Cambrian and Cambrian rocks, Welsh Mountain and Mine Ridge. From the west, extending toward Lancaster from the Susquehanna River, are Chickies, Chestnut, and Manor Hills of Cambrian quartzite.

The northern belt of Triassic strata has abundant soft red shales, which from their use in Adams County, should be suitable for brick making. The central belt is underlain chiefly by Ordovician and Cambrian limestones and shales, the latter resting on Cambrian quartzites. The general section shows:

Cocalico shale	2,000 feet
Ordovician and Cambrian limestone	5,800 "
Cambrian quartzites and phyllites	1,900 "

The Cocalico shale is represented in the south by the Conestoga limestone, 1000 feet thick. Most of these strata are deeply decayed and it is in their residual clays that we look for useful material. The Cocalico shale is blue, gray, green, or purple, weathering lighter in color. It covers areas just south of the Triassic belt, one running west of Denver, one west from Ephrata, uniting beyond Manheim into a large area. Weathering of this shale produces a good material for brick making, the unweathered material being of lesser value. The Glen-Gery Shale Brick Corp. at Ephrata uses the weathered Cocalico shale for the manufacture of common red brick where the Ephrata Shale Brick Co. formerly operated. The clay, which is quite earthy and contains many shaly fragments, is dug by steam shovel from a pit with an irregular face 80 feet long and 35 feet high. This material is burned in 5 beehive kilns.

The Ordovician and Cambrian limestones lie to the south of the shale belt across the center of the county. Generally they are partly covered with yellow and red residual clays, very plastic and of good quality for brick making and other purposes. Tests of similar clays in Cumberland County show that these clays can be used also in making floor tile, pottery, and flower pots. In Lancaster County two plants are using these residuals in making brick.

The Lancaster Brick Company, maker of the Quaker brick, is located one mile northwest of Lancaster, 200 yards south of the Harrisburg pike. The company makes common and face brick from the clay which is a product of weathering of the underlying blue, semicrystalline Conestoga limestone. Numerous small pits have supplied the clay in the past and in 1940 two local areas are being stripped by shovel to supply the clay. In most pits the clay averages 10 feet in thickness. It is quite variable, being a clean gray plastic clay in some places, and a dirty, iron-stained earthy material in others. The varied character apparently reflects the original composition of the limestone from which it is weathered. About 300 tons of clay is hauled each day by a dinky engine to the mill, where it is pulverized by passage through rolls, mixed in a pug mill, pressed, dried, and finally burned in 5 Dutch and 2 beehive kilns. This company has been operating since 1921 and is now faced with the problem of acquiring more land to supply the clay.

The C. Wise Bros. Company is located at Prospect Avenue and Manor Street in Lancaster. This company, which has been making brick for more than 70 years, formerly stripped the clay from around the plant. This area is now built up and the clay is obtained from near Bausman along the Millersville pike, one mile west of the plant. The material being dug is brown and earthy and not very plastic. It contains many small fragments of quartz, weathered from the vein-

cut Conestoga limestone which may be seen at most places in the pit at a depth of 10 feet. The pit is 60 feet long and 30 feet wide. This material is trucked to the plant where, after pulverizing, mixing, and molding, it is burned in 3 Dutch kilns for an average of 70 hours.

From Chestnut Hill and Manor Hills, crossing north of Lancaster to Welsh Mountain, is a discontinuous belt of outcrops of the Lower Cambrian quartzites, phyllites, and quartz schists, the more resistant of which make prominent hills. The weathering of the more schistose beds with a high feldspathic content has formed some good deposits of clay. The clay is mostly light-colored, ranging from a light blue-gray to a browner hue where the iron content is higher. Depending on the contained iron, the clay burns red or gray.

A brown clay weathered from the schistose ferruginous beds that comprise the top of the Antietam formation, was dug for many years just south of Mountville, where the Mountville Brick Clay Company had its plant. This plant has been idle since 1932, the kilns have been dismantled and much of the machinery sold.

The Cambrian rocks, including the Harpers phyllite, and the Antietam and Chickies quartzites, weather at many places to deposits of clay. Welsh Mountain in the eastern part of the county is made up of resistant Cambrian quartzites resting on pre-Cambrian igneous rocks. Along the north slope of the mountain east of Blue Ball, at Narvon, is an area of white clays, residual from the Chickies quartzite and Harpers phyllite. A description of these clays published in Bulletin 112 in 1934 has been revised and is here reprinted.

White clay

This area of residual clays lies along the north slope of Welsh Mountain in eastern Lancaster County, 4 miles west of Honeybrook. Welsh Mountain is made up of resistant Chickies quartzite of Lower Cambrian age. The upper portions of the Chickies are thinner bedded and weather to a white clay while above this lies the Harper phyllite, a greenish schist which weathers to a speckled gray clay. Two companies are working the clays of the ridge at Narvon.

The Whitaker Clay Company, operating here since 1902, has a pit about 1000 feet southwest of the station on a switch from the Pennsylvania Railroad. The pit is cut into the north slope of the ridge and the beds dip southeast 40° into the ridge. At the entrance to the pit, quartzites carrying a 10-foot bed of white clay are to be seen but in the quarry these give way to a main clay bed about 60 feet thick. The main clay is gray and speckled and shows a schistose structure. It carries some sandier layers and some quartz veins. It is probably derived from schistose phases of the upper Chickies quartzite or from the overlying Harpers phyllite. The thinner,

whiter bed in the quartzite is probably derived from the weathering of feldspathic quartzite. Tests made on the main clay show that it has 2.26 percent air shrinkage.¹ At cone 8 (1290° C.) its fire shrinkage is 10.79 percent, its absorption 1.3 percent, and its color buff. At cone 15 (1430° C.) it is overfired. This indicates that it is not suitable for china manufacture. It is sold extensively to steel mills and for filler in linoleum and other products. The company has a well-equipped grinding plant which loads directly into railroad cars.

The Diller Clay and Stone Company (address, 438 E. King St., Lancaster) operates a similar pit about 2,000 feet west. Their pit also cuts into the quartzite and schist of the ridge but the structure is less evident and more complex. In the fall of 1940 they were working a 50-foot face of massive light gray clay. The clay is dug by hand and trucked to the mill, 200 feet from the face, where it is dried in a rotary kiln before treatment in two air separators to eliminate some of the silica and heavy particles. The clay is sacked and shipped for use in steel mill practice, in molding compound for foundry use, and as a filler. Operations began here about 1914.

Sample No. 419. Narvon white clay, Diller Clay Co.

Green properties: Plasticity rating, 60; linear drying shrinkage, 4%.

Fired properties:

	Cone	1	5	7	9	11
	Deg. C.	1160	1205	1250	1285	1325
Linear shrinkage	%	1.0	4.0	6.0	7.0	9.0
Absorption	%	27.1	18.4	13.8	11.1	6.3
Porosity	%	40.3	30.0	24.5	24.0	12.4
Fired color	Dark gray					
P. C. E.	Cone 26. 1595° C.					

Uses. A very white clay, containing a high percentage of free silica in a finely divided form. Its dry strength is very low and it fires to a dark gray color. It may be used as a No. 2 refractory or filler for paint.

The Walters property mentioned in earlier reports has never been opened up. It lies half a mile west of the other properties.

White clays were obtained as a by-product from sand quarries opened in Welsh Mountain east of Narvon.¹

The Diller Sand and Clay Co. operated a sand quarry two miles east of Narvon from 1901 to 1914, which yielded clay made up of equal parts of quartz, muscovite and kaolinite. The output of clay, which was used for foundry facings, was about 30 tons a day.

The Welsh Mining Co. opened three quarries for sand and clay. A 30-foot clay bed three-quarters of a mile southeast of Narvon was abandoned because it dipped so steeply that too much overburden

¹ Ries, H., High Grade Clays of Eastern United States: U. S. Geol. Survey, Bull. 708, p. 90, 1922.

¹ Bascom, F. (and Stose, G. W.), Geology and mineral resources of the Honeybrook and Phoenixville quadrangles, Pennsylvania: U. S. Geol. Survey, Bull. 891, p. 115, 1938.

resulted. The other two pits are $1\frac{1}{2}$ miles east of Narvon. One of them was worked by Paxton-Taggart, Inc., of Philadelphia, for molding sand, but operations stopped in 1932.

The southern portion of the county is underlain by pre-Cambrian schists and igneous rocks. These frequently form residual clays, highly colored. No use is made of them, however.

Selected references to the geology of Lancaster County:

Bascom, F. (and Stose, G. W.), *Geology and Mineral Resources of the Honeybrook and Phoenixville Quadrangles, Pennsylvania*; U. S. Geological Survey, Bulletin 891, 1938.

Frazer, P., *The Geology of Lancaster County: Pennsylvania Second Geol. Survey*, vol. C3, 1880.

Jonas, A. I. (and Stose, G. W.), *Geology and Mineral Resources of the Lancaster Quadrangle: Pennsylvania Topog. and Geol. Survey*, Atlas 168, 1930.

Jonas, A. I. (and Stose, G. W.), *Geology and Mineral Resources of the New Holland Quadrangle: Pennsylvania Topog. and Geol. Survey*, Atlas 178, 1926.

Knopf, E. B. (and Jonas, A. I.), *Geology of the McCalls Ferry-Quarryville District, Pennsylvania: U. S. Geol. Survey, Bull. 799*, 1929.

Leighton, H., *The White Clays of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. 112*, 1934.

Ries, H., *High Grade Clays of the eastern United States: U. S. Geological Survey, Bull. 708*, 1922 (pages 89-91 describe the Narvon clays).

Stose, G. W. (and Jonas, A. I.), *Geology and Mineral Resources of the Middletown Quadrangle, Pennsylvania: U. S. Geol. Survey, Bull. 840*, 1933.

LEBANON COUNTY

Lebanon County lies east of Dauphin County. Its north end is a part of the Ridge and Valley province and is crossed from northeast to southwest by several sharp ridges and intervening valleys. Its middle section is within the Great Valley of low-lying Cambrian and Ordovician limestones and shales. Its southern border is a lowland underlain by the red shales and sandstones of the Triassic, intruded by diabase, and its extreme southeastern corner is the western end of the pre-Cambrian igneous mass of the Reading Hills, flanked on the northwest by Hardyston quartzite of Cambrian age.

The Ridge and Valley section is made up of strata from Pennsylvanian to Lower Silurian in age, dipping steeply to the northwest. The northern border of the county is Sharp Mountain, a ridge of Pottsville sandstone split so as to include a narrow synclinal valley of Coal Measures. To the south of Sharp Mountain is a low valley

underlain by soft, red Mauch Chunk shales and traversed by Stony Creek and by the Reading Railroad. These shales are generally soft enough for brick making and with the railroad passing along the valley there is an opportunity for their development.

South of the valley is a high ridge of Pocono sandstone known as Second Mountain. South of it is a belt of the Catskill shales and sandstones with a few good layers of soft, red shales. This belt is succeeded to the south by a wider belt of Middle Devonian sandstones and shales with much brown, soft shale of the Mahantango or Hamilton formation available. The Reading Railroad and a good highway cross this belt east of Green Point. South of the Devonian shales lies a belt of Middle Silurian shales, the Bloomsburg red and green shales. In the eastern part of the county the Oriskany sandstone and Helderberg limestone separate the Bloomsburg beds from the belt to the north. In the western part they are absent. The Reading Railroad crosses the belt of Bloomsburg reds south of Green Point. They lie just north of Kittatinny (Blue) Mountain. These red beds are soft and usually of excellent quality for brick making. Kittatinny Mountain is a high, sharp ridge of Lower Silurian quartzites. The railroad and Swatara Creek pass through a gap in it and enter the lowland areas of the Great Valley.

The northern half of the Great Valley is underlain by the Martinsburg shales of the Ordovician period and is a hilly area slightly higher than the limestone valley to the south. It is crossed by Swatara Creek and by several highways, such as the highway through Fredericksburg, Ono, and East Hanover. The shales are generally light to dark gray and generally soft enough for brick making, especially where deeply weathered. They are not used in the county, but in Berks County they have been used by the Glen-Gery Shale Brick Corporation in plants near Shoemakersville and Wyomissing, and in Dauphin County at Harrisburg. Sample No. 338 (see Berks County) represents a weathered Martinsburg shale near Shoemakersville. Similar shales could be developed in Lebanon County.

The shale belt ends along a line approximately from Palmyra to Myerstown. South of this line the topography is flatter and the valley is underlain by Ordovician and Cambrian limestones or dolomitic limestones, extensively quarried. These limestones are deeply weathered and are covered with deep pockets of yellow and red, fine-grained, plastic residual clays. These clays are a hindrance to limestone quarrying but might be of use in brick or tile manufacture or in the making of art pottery.

In Lancaster County, the Lancaster Brick Company and Wise Brothers use similar clays in brick making. Miller in Bull. M 20 mentions the Wagner clay pit, three-quarters of a mile north of Avon,

as having used for brick making the residual clay over the Annville limestone. Residual clays are pockety and irregular in occurrence but make excellent products.

The Triassic shales underlie a narrow strip of the southern border of the county. They belong chiefly to the Gettysburg division of the Triassic and are soft red shales, except where discolored and slaty, close to diabase intrusions. Similar shales have been used in Adams, York, and Dauphin Counties in face brick manufacture. The Royalton Face Brick Company in Dauphin County used about 20 feet of weathered Gettysburg shale in brick making. In Lebanon County similar shales might be developed south of Cornwall or in the Mt. Gretna district along the Pennsylvania Railroad.

The pre-Cambrian igneous rocks of the Reading Hills in the southeast corner of the county will probably yield no residual clays of value. Siliceous white clays might be found in the residual from the belt of Hardyston quartzite that flanks the igneous mass.

Selected references to the geology of Lebanon County:

d'Invilliers, E. V., The Iron Ore Mines and Limestone Quarries of the Great Valley in 1886: Pennsylvania Second Geol. Survey, Ann. Report for 1886, Part IV, 1887.

Jonas, A. I. and Stose, G. W., The Lancaster Quadrangle: Pennsylvania Topog. and Geol. Survey, Atlas 168, 1930.

Miller, B. L., Limestones of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 20, 1934.

Stose, G. W. and Jonas, A. I., Geology and mineral resources of the Middletown Quadrangle, Pennsylvania: U. S. Geol. Survey, Bull. 840, 1933.

Willard, B., Guide to the geology of the Upper Schuylkill Valley: Pennsylvania Topog. and Geol. Survey, Bull. G 14, 1939.

LEHIGH COUNTY

Lehigh County lies between Berks and Northampton Counties in the eastern part of the State. Its northern boundary is the sharp crest of Kittatinny Mountain, the southern mountain of the Ridge and Valley section. The northern two-thirds of the county lies within the Great Valley. South of this lowland the county is crossed by South Mountain and other ridges, a part of the Appalachian Mountain province of pre-Cambrian igneous rocks.

South of these ridges and along the southern border of the county is a narrow belt of the Triassic lowlands section, underlain by red shales, sandstone, and diabase intrusions. Lehigh River borders the county on the northeast and then crosses it through Catasauqua, Allentown, and Bethlehem.

The Great Valley is underlain by folded Cambrian and Ordovician shales, slates, and limestones reduced to a low rolling plain or to flat topography. Its northern half is underlain by the Martinsburg shales and is a rolling plain, often termed the Slate Hills. The Martinsburg formation is made up of gray to black slates and sandstones. Soft shale is rare as metamorphism has converted this into true slates, which are extensively quarried across the northern half of the county. Long weathering sometimes reduces the slate to a light gray or brown residual soil which might be used in brick making. Behre in Bull. M 16, p. 353, notes such old clay pits in weathered slate one-quarter of a mile north of Wernersville and also a mile north of Walberts. On the whole, however, the slate belt does not carry good brick shales. Glacial clay, usually bouldery and mixed with pockets of sand and gravel, is common in the area and might be used in brick making, although not as good as the glacial and residual clays to the south.

South of the Slate Hills, the surface of the valley is much lower and flatter and is underlain by Ordovician and Cambrian limestones extensively quarried for portland cement manufacture and other uses. Allentown and Bethlehem are in this limestone valley. There is but little shale in the valley and brick materials consist of glacial clays and clays derived by residual decay of the underlying limestones, the two types often mixed. These clays are red-burning plastic clays suitable for the manufacture of common brick, face brick, drain tile, some types of art pottery, and flower pots. Their greatest faults are the presence of boulders and stony matter, and the fact that they are usually in irregular pockety deposits with an irregular limestone bottom.

Miller in the Allentown quadrangle report (Atlas 206) describes ten brickyards in these materials in eastern Lehigh County. Six of them were then (1925) idle or abandoned, and four were in operation. In 1940 only one was in operation. The former plants were in the northwestern and the southern parts of Allentown, southeast of Catasauqua, west of Emmaus, and at Bingen on the Lehigh-Northampton County line.

At present (1940) the Lehigh Brick Company is the only producer. The plant is $1\frac{1}{2}$ miles south of Allentown and uses residual and glacial clay with a depth of 6 to 20 feet. The clay is crushed in a centrifugal crusher and burned in 8 round kilns and 2 large continuous kilns.

The South Mountain area is a highland of pre-Cambrian gneisses flanked by Hardyston quartzite of Cambrian age. Residual decay of the gneiss yields a kaolinitic sand which is not of sufficient clay content to be classed as a clay. The more sericitic beds of the Hardyston quartzite should yield siliceous kaolins but none are now known.

The Triassic rocks on the south border are of no value in brick making as the Triassic of that area is chiefly a resistant siliceous conglomerate, intruded and baked by large diabase masses.

Selected references to the geology of Lehigh County.

Bascom, F., et al., Geology and mineral resources of the Quakertown-Doylestown district, Pennsylvania and New Jersey: U. S. Geol. Survey Bull. 828, 1931.

Behre, C. H., Jr., Slate in Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 16, 1933.

Lesley, J. P. (et al.), The geology of Lehigh and Northampton Counties: Pennsylvania Second Geol. Survey, vol. D 3, pt. 1 and Atlas, 1885.

Miller, B. L., Mineral resources of the Allentown Quadrangle: Pennsylvania Topog. and Geol. Survey, Atlas 206, 1925.

Miller, B. L., Limestones of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 20, 1934.

LUZERNE COUNTY

Luzerne County lies east of Columbia County in the northeastern part of the State. It is mostly within the Ridge and Valley section, but with its northwest corner a part of the Allegheny Mountain plateau and its eastern edge part of the Pocono plateau. These high areas are underlain by Pocono and Catskill sandstones. The exposed strata in the county range from Pennsylvanian Coal Measures down to the Hamilton formation of Middle Devonian.

The Coal Measures underlie two synclinal valleys or basins rimmed by high ridges of Pocono sandstone. The northern area is the western end of the Northern Anthracite Field. This basin extends from the northeast part of the county near Pittston south of west to Hartville and includes the great coal mining area of Pittston, Wilkes-Barre, and Nanticoke. The valley is traversed from West Pittston to Nanticoke by the Susquehanna River, which, north of Nanticoke, passes out of the Coal Measures into the surrounding Mauch Chunk shales.

The second coal basin is a part of the Middle Anthracite Field broken up into minor basins around Hazleton. It lies along the southern border of the county. The Coal Measures in these basins consist of dark, slaty shales, some sandstones, and many beds of anthracite resting on Pottsville sandstone and conglomerates which form rims around the coal-bearing areas. Fire clays do not accompany the anthracite beds and the shales are usually too slaty or too carbonaceous to use in brick making. Shaw in Bulletin M 10 gives tests on one dark shale (no. 59) under the Ross coal, half a mile west

of Forty Fort in the Wilkes-Barre area. This shale was 12 feet thick, dark slate color and had good plasticity. Its water of plasticity was 28.06 percent; volume drying shrinkage 7.17 percent; maximum volume burning shrinkage 34.00 percent at cone 9; its time of slaking 22½ minutes; its point of fusion cone 16. This shale could be used in brick manufacture.

The Hazleton Brick Company built a plant at West Hazleton in 1919, the only brickyard operating in Luzerne County in 1940. Local shale is used for making various kinds of face brick. The seven down-draft kilns have a capacity of 60,000 brick per 8-hour day.

The Coal Measures range in thickness from 500 to 900 feet. Surrounding the coal basins and the terraces of Pottsville sandstone are low areas underlain by the red Mauch Chunk shale and sandstone. These beds range in thickness from 2,000 feet around the Southern Anthracite Field to but 150 feet near Pittston. They are chiefly soft red shales and contain many beds of value in brick making. North of the Hazleton coal basin a wide belt of the Mauch Chunk beds forms Conyngham Valley and is traversed by Nescopeck Creek. It extends east to the Lehigh River which cuts into the red shales through White Haven and Lehigh Tannery and to the southeastern corner of the county. The northern border of this Mauch Chunk belt is Nescopeck Mountain.

The Northern Anthracite Field is surrounded by a thinner and narrower band of the Mauch Chunk shales forming a narrow belt just north of Wyoming Mountain south of the Wilkes-Barre basin and a second belt north of the basin and just south of Shickshinny Mountain. The Susquehanna River and Highway 11 follow this belt from West Nanticoke to Shickshinny. West of Shickshinny the two belts merge into one at the end of the coal basin.

High Pocono ridges rim the coal basins, Shickshinny Mountain and Wyoming Mountain around the northern basin, and Nescopeck Mountain on the north edge of the Hazleton basin. Between Nescopeck Mountain and Wyoming Mountain is a low anticlinal area of wide extent exposing Middle Devonian and Catskill beds. In the western end of this belt, crossed by the Susquehanna River, shales and sandstones of Hamilton, Portage, and Chemung formations appear. The softer gray shales of the Hamilton could be worked along the river at Nescopeck, Beach Haven, and Wapwallopen. The eastern half of this anticlinal area is underlain by Catskill red sandstones and shales, some of which are soft and, therefore, workable.

Willard in Bulletin G 19 extends the soft red Mount Pleasant shales of the upper Catskill over the larger part of the area formerly mapped as Pocono in the eastern plateau area, as around Bear Creek.

North of Shickshinny Mountain is another large expanse of Catskill beds with a smaller area of Chemung sandstones and shales to the west in the Harveyville and Huntington Mills district. In the Catskill beds there should be soft red shales for brick making.

Selected references to the geology of Luzerne County:

Shaw, J. B., Fire Clays of Pennsylvania: Pennsylvania Topog. and Geol. Survey Bull. M 10, 1928.

White, I. C., The Geology of the Susquehanna River Region in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland: Pennsylvania Second Geol. Survey, vol. G 7, 1883.

Willard, B., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

LYCOMING COUNTY

Lycoming County is one of the north-central counties. Its northern half is in the Allegheny Plateau province and is chiefly a wooded plateau upland deeply trenched by south-flowing tributaries of the Susquehanna River, Pine Creek, Little Pine Creek, Lycoming Creek and Loyalsock Creek. The southern border of the plateau, the Allegheny Front, slopes down into the broad valley of the West Branch of the Susquehanna River, which is carved from the Lower Devonian and Upper Silurian limestones. The river flows east to Muncy, making there a southwest bend. South and west of the river in the loop made by it, the southern townships are a part of the folded Appalachian Mountains, chiefly Tuscarora sandstone ridges with valleys of Ordovician shale and limestone between them. The trend of folding in the county is nearly east-west. The strata exposed range from the Allegheny group of the Coal Measures in the north, down to the Ordovician limestones of the southern valleys.

Allegheny group. In the northern half of the county the higher knobs and plateaus in the gentle synclinal folds are capped by beds of the Allegheny group. Their distribution is as follows: (1) a small area on the high knobs in Phunketts Creek Township; (2) a small area in the southeastern part of Cogan House Township; (3) several small tracts along the western county line; (4) a large basin east and west from Ralston in the northeastern part of the county; (5) the Little Pine Creek basin north of English Center in Pine and McHenry townships.

In these coal basins the entire Allegheny group is present. The general section appears in the Ralston-McIntyre basin as follows:

Feet	
2-5	Coal—E or Upper Freeport
80	Sandstone
7	Coal—D or Lower Freeport (with 3 foot parting)
21	Sandstone
1	Coal—C' or Upper Kittanning
13	Sandstone
1-3	Coal—C or Middle Kittanning
20	Shales
4½-7	Coal—B, Lower Kittanning or "Big Bed"
20	Shales
9	Coal and shale. A—or Brookville-Clarion.

The Lower Kittanning coal is the most important and the Upper Freeport next. The others are dirty and shaly. In the old reports mention is made of fire clays one to three feet thick under the various coals. No recent study has been made but it would seem probable that fire clays and brick shales could be expected in these Coal Measures.

Pottsville series. The Pottsville series is confined to the uplands in the northern part of the county. It occupies much larger areas than the Allegheny group. It averages 125 feet thick and is chiefly massive sandstone, making wooded plateaus. Along the western and northwestern borders of the county valuable flint clays occur either on or within the Pottsville, representing either the Brookville or the Mercer clay. The first of these is a deposit in Brown Township two miles north of Pump Station and three-quarters of a mile east on the Pipe Line road. Here are old pits on a wooded plateau of sand rock. Flint clay was dug from these and shipped during World War I. At present no good exposures can be seen but sample 299 represents the clay as piled near the pits. This, of course, is not plastic. It fires cream to buff with a firing range of 1000° C to 1350° C, and fuses at cone 31½ (3074° F or 1690° C). It is a flint clay suited to the manufacture of fire brick.

Clay was seen in the pit of the Kelsey Mining Company, half a mile south of Haneyville on the western county line. Under a three-foot soil cover, the pit shows 4 feet of flint clay, and beneath it 3 feet of softer shaly clay. "Iron balls" (siderite and limonite nodules) and crevice clays make sorting necessary. The clay is trucked 7 miles to the railroad at Waterville and has been shipped to clay plants in New York, Ohio and Pennsylvania. Sample 279 shows that it burns to a cream color, with a firing range from 1000° C to 1350° C. It

fuses at cone 33 (3173° F or 1745° C). It is an excellent flint clay for refractories.

Flint clays have not been reported from the other Pottsville areas but they should be looked for, especially near or on top of the Pottsville sandstones or under the lower coals of the Allegheny group.

Mauch Chunk series. The Mauch Chunk of Upper Mississippian age, forms a thin band of red shales and some sandstones just beneath the Pottsville. It ranges from a few to 120 feet in thickness. It generally is not in accessible position for use in brick making although its red shales should make brick.

Pocono series. Below the Mauch Chunk series the Pocono sandstones of Mississippian age appear. They are 300 to 500 feet thick, mostly thin-bedded sandstones. They make up the greater part of the middle slopes of the northern townships. Carrying but little shale and no clay beds, they are of little interest to the clay worker.

Catskill series. The red phase of the Upper Devonian is called the Catskill series. It is made up mainly of red shales and reddish sandstones. In the northern half of the county it makes the valley walls of Pine, Little Pine, Lycoming, and Loyalsock creeks. It also forms wide areas in Cogan House and Cascade townships and crosses the county in a wide belt from Salladasburg to the eastern boundary. Tests made of the better red shales of the Catskill in other counties (see Clinton County) prove them to be good for face brick manufacture. Their long outcrop on the highways and railroads, as along Pine and Lycoming Creeks, makes them very accessible and they might well be developed.

Middle Devonian shales. The Chemung, Portage, Genesee, Hamilton and Marcellus divisions of the Devonian form a belt four miles wide, extending from the west county line just north of Jersey Shore, east to the Columbia County line and swinging back along the Montour and Northumberland county lines to cross the Susquehanna in Brady Township. They form the hilly country between the Allegheny Front and the West Branch, through Jersey Shore and Williamsport. The series is made up of bluish sandstones and shales with the shaly portions available for brick making. The West Branch, through Jersey Shore and Williamsport, flows in a valley of Lower Devonian and Upper Silurian limestones. These pass east around Muncy and loop back west again in the southern part of the county. Within this great loop Tuscarora quartzite makes Bald Eagle Mountain, North White Deer Ridge and South White Deer Ridge. On the outer flanks of these mountains are the Clinton shales. They are especially prominent south of the Susquehanna River from Jersey Shore to Muncy. They

are about 1,000 feet thick and are made up chiefly of colored shales. At Castanea (Clinton County) they are used in brick making and they constitute one of the good sources of shale for such purposes. They could be developed south of Jersey Shore, Williamsport or around Muncy.

Nippenose and Mosquito Valleys are eroded in the anticline of Tuscarora quartzite. In them are Ordovician shales and limestones. No railroad enters these valleys and no tests have been made of their shales or clays. Any clays present would be of a residual type, resting on the limestone bottoms. Such clays might be plastic colored clays, or even white siliceous clays of some value.

Summarizing the clay and shale resources, it is seen that flint fire clays are known in the Pennsylvanian strata in the northwest, thin plastic fire clays accompany the small Allegheny coal basins in the north, shales for brick making should be found in the Catskill beds of the northern part of the county and in the Clinton of the southern part of the county, and plastic residual clays may overlies the Ordovician limestone in the Nippenose and Mosquito Valleys.

Physical tests of Lycoming County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point cone	Best burning range (cones)	Firing color	Suggested uses
279	21.8	1.5	2.	10.	4.7	4	33	07-11	Cream	Fire brick
299	19.3	0.2	0.5	15.	5.0	9	31½	07-11	Cream to buff	Fire brick

279. Haneyville, Kelsey Mining Co.

299. Brown Township, 2 miles north of Pump Station.

No chemical analyses were made.

Selected references to the geology of Lycoming County:

Sherwood, A., and Platt, F., The Geology of Lycoming and Sullivan counties: Pennsylvania Second Geological Survey, vol. G-2, 1880.

Sisler, J. D., Bituminous coal fields of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 6, pt. II, 1926.

McKEAN COUNTY

McKean County is in the high plateau country along the New York-Pennsylvania boundary between Potter and Warren Counties. It is drained chiefly by Kinzua Creek, Sugar Run, and Corydon Creek to the west, by Tunungwant Creek in the north-central part and by the northward flowing Allegheny River in the eastern part. The county is practically all outside the glaciated area but the larger streams flow in wide valleys floored with glacial deposits.

The strata of the county lie nearly horizontal and include the lower half of the Allegheny group, the Pottsville series, the Mississippian (Knapp formation), and the Oswayo, Cattaraugus and Chemung divisions of the Upper Devonian.

The Allegheny group occurs in the Clermont, Norwich, and Alton basins. The total thickness averages about 120 feet. The exposed strata extend from the shales above the Middle Kittanning coal to the Clarion coal and its underlays, resting on the Pottsville sandstones. Thin coals are found at the Lower Kittanning and the Clarion horizons. A thin limestone, the Clermont, occurs 10 to 30 feet below the Lower Kittanning coal and probably represents the Vanport. Shales that might be used in brick making occur above the Middle Kittanning coal, and above and below the Clermont limestone. Fire clays 2 to 3 feet thick occur below the Lower Kittanning and the Clarion coals. These shales and clays are utilized by two companies, the Clermont Clay Products Company at Clermont and the Mt. Jewett Fire Clay Company, south of Mt. Jewett. One of the dark shales used at Clermont (no. 195) shows very good plasticity and a low green strength. It fires to a brown to black color with a firing range from 1100° to 1150° C. It may be used with other clays in making sewer pipe.

Until 1936 the Clermont Clay Products Co. manufactured clay conduits, using only the fire clays. The clay 4 to 19 feet thick was mined through a 70-foot shaft, passed through crusher and dry pans, screened by gravity screens, tempered in wet pans, and molded in vertical sewer pipe presses. It was floor dried, and burned and salt glazed in beehive kilns. In 1940 the plant had been idle four years but has a stock of hollow conduit of various kinds. The Mount Jewett Clay Company mines fire clay 3 miles south of Mount Jewett. The clay is a plastic fire clay underlying a thin coal that may be the Lower Kittanning, Clarion, or Mercer coal. The overburden 5 to 35 feet thick is removed and the clay is taken out of open pits. The company does no manufacturing but produces and ships much crude or screened fire clay, screening from 1 inch to 30 mesh. The clay is a tough, whitish fire clay (no. 426, 427) fusing at cone 30 and is

suitable to the manufacture of refractories, sewer pipe, or buff face brick.

Building brick, paving brick, and floor tile were made formerly at Kushequa and at Sargent from local clay, but the business has been abandoned and the plants torn down.

Pottsville series. Sandstones and conglomerates of the Pottsville series form most of the upland areas of the county. The Mercer shales, coals, and clays lie below the upper sandstones. Here are three thin Alton coals with their fire clays and shales. The chief clay underlies the upper Alton coal. This may be the clay worked by the Mt. Jewett Fire Clay Company (samples 426, 427). Below the Mercer horizon are the Connoquenessing sandstones, then the Sharon (Upper Marshburg) coal and shale, the heavy Olean conglomerate, and at the bottom the Lower Marshburg coal and clay. The latter is exposed near Bingham on the Baltimore & Ohio Railroad. The gray clay there is about 12 feet thick and might be of value.

Knapp formation or Mississippian. Below the Olean conglomerate and its Lower Marshburg coal and clay there lies 40 to 70 feet of sandstone, shale, and conglomerate, the exact correlation of which has been in dispute. Caster and Fettke place them in the Mississippian. Shales found with the conglomerates of the Knapp formation at Kushequa have been used in red brick manufacture by the Kushequa Brick Company (sample 423).

Oswayo member. The boundary between the Mississippian and Devonian is set by Caster at the Marvin Creek limestone just under the Kushequa shale. Below these lie the Oswayo beds, about 200 feet thick, and made up chiefly of greenish gray shales and thin sandy beds. Near the base is a second limestone which Ashburner mistook for the Marion Creek, according to Caster. The Oswayo includes shales which could be used in brick making but are usually not as valuable as are the older beds. Oswayo shales crop out along the main valleys, as do the remainder of the Devonian beds to be discussed. They are not now used in making brick.

Cattaraugus formation. Beneath the Oswayo shales is a series of reddish shales and sandstones carrying conglomeratic beds. The conglomerates in the series are the Tuna or Killbuck at the top, the Salamanca in the middle, and the Wolf Creek (Panama) at the base. The whole series is correlated with the First, Second, and Third Venango oil sands.

As members of the Cattaraugus formation, Caster lists in descending order the Saegertown, North Warren, and Amity shales. Use is

made of the Amity shale by the Hanley Company at its plant at Lewis Run, south of Bradford. Fettke's section (Bull. M 21, p. 36) follows:

Feet

45	Concealed to top of red Cattaraugus
5	Greenish gray sandstone
113	Concealed
6	Greenish gray and reddish gray shaly sandstone
11	Greenish gray sandstones
45	Greenish gray shales
15	Variegated red and green shales
14	Red to purple sandstones
5	Greenish gray shales, sandy
21	Brick-red shales
13	Concealed to base of Cattaraugus

The shale used is the 15 feet of red and green variegated. Sample 332 shows that this has good plasticity and fair green strength. It fires salmon to brown with a burning range from 1050° to 1150° C, and is suited to the manufacture of face brick and tile. The plant is equipped with round and with tunnel kilns and manufactures wall tile, floor tile, hollow tile, and face brick.

The above section and practical use indicate that the Cattaraugus shales can be used in the manufacture of a variety of red ceramic products.

Chemung group. The shales and sandstones below the Cattaraugus formation in McKean County have been and will here be termed Chemung, although they are in reality younger than the true Chemung to the east. They are placed by Caster in the Chadakoin stage of the Chautauquan series. Their thickness as exposed in the county is about 2,000 feet. They are exposed in the lower river valleys only, and consist of gray shales, gray sandstones, fine-grained, chocolate-brown sandstones (including the Bradford "sand"), and at the base some dark shales. In the series are many shales that could be used in making brick. Just south of Bradford, in the old Penn Block Company quarry, 25 feet of light gray shale (sample 333) is exposed that has good plasticity and fair green strength. It burns salmon to brown with a burning range of 1100° to 1150° C. It is suitable for the manufacture of face brick, hollow tile, and drain tile. The plant is no longer in operation but formerly made red brick.

Much of the Chemung shale is to be seen along the Allegheny River from Port Allegany to Smethport. Sample 162 is a typical one. It consists of 12 feet of olive-green shale exposed along the roadside south of Larabee at the Allegheny River. This shale has good plasticity and fair green strength. It burns to a light to dark red

color, overfiring suddenly at 1200° C. It is suited to the manufacture of face brick or tile.

In summary: Shales and thin fire clays occur in the lower Allegheny group and Pottsville series and have been used; red and gray shales in the Mississippian and the upper Devonian have been worked.

Physical tests of McKean County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point (cone)	Best burning range (cones)	Firing color	Suggested uses
162	21.73	3.8	6	236	5.1	4	14		Light red to dark red	Drain tile or face brick
195	20.4	6.3	10	117	3.1	05	12	03-1	Brown to black	Sewer pipe mixture
332	22.6	4.8	5	153	7.7	1	13	05-1	Salmon to brown	Face brick, hollow tile, drain tile
333	22.0	2.1	10	144	5.7	02	12	03-1	Salmon to brown	Face brick, hollow tile, drain tile
Plasticity rating				Maximum volume shrinkage						
423	75	5.2		21.0	9	15			Red to brown	Face brick, tile
426	80	4.0		18.0	9	30			Buff	Buff face brick, sewer pipe, refractories
427	75	5.2		9.0	9	30			Cream to buff	Refractories

Chemical analyses of McKean County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
195	10.26	47.14	11.05	1.63	19.40	5.10	1.70	.95	.50	.17	.55	2.20
332	5.63	54.28	7.22	.20	24.12	.98	2.11	.82	1.97	.10	.18	2.30
333	4.82	60.03	7.97	.92	22.77	.73	2.17	.67	1.44	.05	.13	.77

162. Shale, south of Larabee.
 195. Dark shale, Clermont.
 332. Shale, Hanley Company, Lewis Run.
 333. Shale, Penn Block Co., Bradford.
 423. Shale, Kushequa
 426. Fire clay, Mt. Jewett.
 427. Fire clay, Mt. Jewett.

Selected references to the geology of McKean County:

Ashburner, C. A., The geology of McKean County: Pennsylvania Second Geol. Survey, Report R, 1880.

Caster, K. E., Stratigraphic relationships in northwestern Pennsylvania: Geol. Soc. of America Bull., vol. 44, pages 202-203, 1933.

Fettke, C. R., Bradford Oil Field: Pennsylvania Topog. and Geol. Survey, Bull. M 21, 1938.

MERCER COUNTY

Mercer County is in the west end of the State between Lawrence and Crawford Counties. It is thoroughly glaciated and has the rolling topography produced by glacial deposits and glacial scouring. Most of the larger streams flow in wide valleys, many of which are deeply filled with glacial material. Swamps are numerous and frequently two streams rise in a common swamp and flow away in opposite directions after the manner of the "through valleys" of New York State. Rock outcrops are rare.

The western portion of the county is drained by the Shenango River which enters the northwest corner of the county at Jamestown, and with several large bends flows south through Greenville and Sharon, leaving the county in its southwestern township. The central part is drained largely by Neshannock Creek, which rises north of Fredonia, flows past Mercer and south into Lawrence County. French Creek touches the northeastern corner of the county, Sandy Creek and Wolf Creek drain the eastern part, and flow south in the southeastern portion.

The county is well served by railroads, which have little difficulty in crossing it in any direction. The Bessemer & Lake Erie crosses it from the northwest to southeast, touching Greenville, Mercer, and Grove City. The Pennsylvania Railroad follows the Shenango River, reaching Sharon and Jamestown. Another branch of this railroad passes through Leesburg, Mercer, and Stoneboro, where it connects with the New York Central which extends to Jamestown and beyond. The Erie Railroad follows the Shenango River to Greenville and Kennard.

The exposed strata of the county are sedimentary rocks lying practically horizontal. They include 200 feet of the lower Allegheny group, 250 feet of the Pottsville (the entire group), and about 150 feet of the upper Mississippian rocks. The Allegheny rocks occur only in the higher hills of the southeast half of the county, covering about 50 square miles in all, and much of this is deeply covered with glacial material. Some of the larger tracts underlain by the Allegheny group lie south of Stoneboro, southeast of Jackson Center, south of Pardoe, and south and east of Grove City.

The northwestern townships and the valley of the Shenango River are all in the Mississippian strata but by far the larger part of the county is underlain by rocks of the Pottsville series. The general section of the lower Allegheny group is about as follows:

Feet	
30	concealed
2	Darlington coal
5	clay
40	sandy shale
2	Lower Kittanning coal
45	concealed
15	Vanport limestone
3	shale
1	Scrubgrass coal
25-40	shale and sandstone
4	Brookville coal (formerly Pardoe)
5-15	clay and shale

The Brookville is the only coal of any importance in the county and it is mined extensively. Clays are present under the coals but little attention has been paid to them as they are generally thin. The Darlington coal is said to have a 5-foot clay beneath it along Wolf Creek. The Lower Kittanning coal should have a valuable underclay but its outcrops are almost entirely covered with drift. Clay beneath the Brookville coal and separating it from the Homewood sandstone is said to be 4 feet thick near Grove City and to be from 2 to 3½ feet thick south of Stoneboro. On account of the active mining of this coal the clay may some day be utilized. No tests have as yet been made on it.

The section of the Pottsville series is about as follows:

Feet	
50	Homewood sandstone, massive
10	shales
2	Upper Mercer limestones
2	Upper Mercer coal
25	dark iron-bearing shales
2	Lower Mercer limestones
5	shale
2	Lower Mercer coal
16	shales
40	Upper Connoquenessing sandstone
10	shale
1	Quakertown coal
40	shale
30	Lower Connoquenessing sandstone
30	Sharon shale
3	Sharon coal
5	fire clay and shale
20	Sharon conglomerate

None of the coals of the Pottsville series is now worked and exposures therefore are rare. The Sharon coal was extensively worked years ago but has long since been exhausted. The Homewood sand-

stone of Keel Ridge, west of Mercer, has a 3-foot clay beneath it; nearby this clay was but $1\frac{1}{2}$ feet thick. It evidently was of no great importance. A sporadic coal and clay was noted in report QQQ at Maple Grove on the Venango County line north of Sandy Creek. This coal was about 6 feet above the Lower Mercer limestone and carried a 4-foot bed of clay between two benches of thin coal. A fire clay occurs below the Lower Mercer coal at several localities. One mile west of the Venango County line on Sandy Creek this clay ranged from 2 to 4 feet thick. South of Greenville a 3-foot clay is noted four feet below the Lower Connoquenessing sandstone. At Sharon 3 to 4 feet of fire clay and shale underlie the Sharon coal. These scattered notes from report QQQ show that even when these coals were being mined the clays attracted little attention and they are probably of little value.

The shales of the Pottsville series are generally too sandy or too dark and iron-bearing to be of much value for brick-making. There are among them, however, some lighter colored ones which are suitable for common red brick and tile. Such a shale is that collected just south of the county line and west of New Wilmington (see sample 223, Lawrence County). The shales above the Sharon coal in the vicinity of Keel Ridge are said to be soft and gray, which should make them of value in brick making.

The rocks of the Upper Mississippian which underlie the Sharon coal are generally sandy shales, many of them being flagstones. In places these shales are less siliceous and might be used for making brick. At Orangeville, on the Pymatuning Creek, near the State line, 40 feet of such shales are to be seen. They are red and gray at the top and become finer and darker toward the base.

The glacial deposits include blue clays weathered to buff or yellowish color when exposed. A sample of the common glacial material as seen around West Middlesex was taken at a point about 2 miles north of that borough. This clay (224) was somewhat more sandy than many blue glacial clays but represented the surface material. It showed poor plasticity and a low green strength. It fired to a red to brown color and had a firing range from a little below cone 010 to cone 05 and seemed suitable for drain tile manufacture as well as common red brick. Glacial clays were formerly used to some extent for making red brick and tile, but now shale is found to be more satisfactory and the demand is for a face brick which cannot generally be made from a glacial clay.

MIFFLIN COUNTY

Mifflin County lies east of Huntingdon and Centre Counties. It is traversed by the Juniata River which enters along its southern border and passes into Juniata County along the eastern border. Tributaries to the Juniata drain the northern and northeastern portions. The county lies wholly within the folded Appalachian province and its topography consists of northeast-southwest trending ridges and valleys. Its western border is mostly along Standing Stone and Long Mountains of Tuscarora sandstone. Lengthwise through the middle of the county passes a second Tuscarora ridge, Jacks Mountain. The eastern border is ridges of the same sandstone, Black Log Mountain and Blue Mountain. Between the western border and Jacks Mountain lies an antilinal valley exposing Ordovician shales and limestones. Between Jacks Mountain and the eastern border lies a synclinal area carrying Clinton shale and most of the Devonian section.

In the area west from Jacks Mountain, including Belleville and Reedsville, the available clays would be reddish residuals resulting from the weathering of the Ordovician limestones. The available shales would be the Upper Ordovician cropping out around Reedsville and Milroy. Neither seems of much importance. Northwest of Milroy about two to three miles on Route 322, in the State Forest, Clinton shales overlie the Tuscarora sandstones in a small area. These are soft, purple, and greenish-gray shales. Sample 319 taken from a roadside shale pit shows fairly good plasticity and a low green strength. It fired salmon to reddish brown with a burning range of 1100° to 1500° C and would make a fair brick.

East of Jacks Mountain the most prominent shales are the Clinton shales. The Juniata River and Pennsylvania Railroad follow them southwest from Lewistown, as does also the railroad northeast from Lewistown. These were not tested but, judging from the test of sample 319 and the Clinton shale tests in Juniata County, brick and hollow tile could be made from them. In the north end of the county in Decatur Township north of Wagner, and in the south end, west of Newton Hamilton, Devonian shales crop out and include bluish brick shales.

For bibliography and tests see Juniata County.

MONROE COUNTY

Monroe County is on the eastern border of the State north of Northampton County. Delaware Water Gap and Pocono Mountain are well-known features. The northwest half of the county is part of the high Pocono Plateau region made up of Catskill strata dipping gently northwestward. To the east and south this plateau ends in an escarpment sloping down into areas of rolling hills of Portage and Chemung strata and these in turn to somewhat folded lower Devonian strata near the Delaware River, particularly southwest of Marshall Creek. The southern border of the county is the high Kittatinny Mountain of tilted Shawangunk sandstone through which the Delaware River breaks at Delaware Water Gap.

The northwest townships have brick-making material in the Catskill (Damascus) shales and possibly glacial clays.

The northeastern townships and a belt running west from Tannersville are underlain by basal Chemung and Portage shales and sandstones. Many of these shales are suitable for brick making and have been used in other counties. South of the Portage beds lie outcrops of the Genesee and Hamilton strata of the Devonian. These are chiefly made up of sandstones and can furnish very little soft brick shale. In the lower lands are softer dark Marellus shales and lower Devonian limestones. Some of the Marellus shales could be used in the manufacture of common or face brick but they are not of high quality.

The Oriskany sandstone forms a somewhat irregular ridge across the southern part of the county, separated from the more prominent Kittatinny Mountain by a belt of Clinton (Bloomsburg) shale and the Helderberg limestones. Near Kunkletown the Oriskany ridge yields valuable white residual clays which have been extensively developed. For many years, white clays were mined near Saylorsburg. They have been described by Peek, and more recently by Leighton. His description, with notes by R. M. Foose, is as follows:

Northeast from Saylorsburg is a prominent ridge known as Cherry Ridge. It is made up of steeply tilted Oriskany sandstone and the underlying Stormville shale and Bossardsville limestone. The beds dip into the hill to the southeast. Southwest from Saylorsburg a similar ridge, known as Chestnut Ridge, has essentially the same structure. The shaly limestones and shales underlying the coarse Oriskany sandstone along these ridges are deeply weathered to a residual clay, the different layers showing clays of different colors. Some of the beds are carbonaceous and black, many are gray, a few are very white. The dip of the beds is generally about 30 to 60° toward the south or southeast so that an entry driven into the ridge

cuts across the beds and eventually reaches the overlying Oriskany sandstone as a hanging wall.

Present operations. The Universal Atlas Cement Co. alone operates in the district at present and their product is a white, siliceous clay which is used by them to whiten their portland cement. Their predecessors, Atlas Portland Cement Co., are said to have drilled most of the two ridges and to control most of the good clay deposits between Saylorsburg and Kunkletown. Their earlier operations were confined to an area 1 mile northeast of Saylorsburg on Cherry Ridge. Here the company sank several shafts and cross-cut from them toward the ridge, exposing a few thick beds of gray sandy clay. The shafts have been idle since 1930. The best clay was the bed directly under the hanging wall of Oriskany sandstone. It had a width of about 20 feet. The clays were loaded on a branch of the Delaware, Lackawanna and Western Railroad 0.3 mile west toward Saylorsburg. The workings as they were in 1922 are described by Peck.

Tests of the crude clay made by Ries¹ show at 1150° C an absorption of 12.8 percent, a porosity of 1.5 percent and a buff color. The product was steel hard. At 1300° C the absorption was 31.2 percent, the porosity 2.9 percent and the color light gray.

The only active white clay property in 1940 is that of the Universal Atlas Cement Company. The office and stock pile are on Chestnut Ridge just south of Kunkletown, and the clay pit, 2,000 by 50 by 40 feet, is four miles east near the summit of the ridge. The clay is dug by drag-line shovel, loaded in cars, and hauled by steam locomotive over a private railroad to the stock pile, from which it is taken as needed by truck to a large tipple over the railroad at Kunkletown. The pit is operated only from April to October, at a rate of about 300 tons a day. The raw clay is shipped to the company's cement mill at Northampton.

Two pits south of Kunkletown have not been used since the present one was opened in 1934.

Earlier operations. In earlier years the clays of the Saylorsburg region were exploited much more extensively and used for a number of purposes. In the anticipation that some of the industry may be revived it seems well to review the earlier history and development as recorded by Peck.

The first development of the white clays was in 1891 when Oscar Drehr built a plant in Saylorsburg and attempted to make enameled brick but with little success. In 1894 Blanchard Bros. of Newark, N. J., took over the plant and made for some years, dry pressed brick.

¹ Ries, H., High Grade Clays of Eastern United States: U. S. Geol. Survey, Bull. 708, p. 113, 1922.

The plant at one time employed 150 men. It changed hands several times and in 1908 the Keystone Clay and Reduction Co. began operating it for the production of washed clay. In 1919 this company was hoisting about 60 tons of clay daily from a number of shafts in the heart of Saylorsburg and producing about 30 tons of washed clay. Most of the clay went to the New England paper mills. Some was shipped to rubber companies and some to the manufacturers of water paints. The plant was well equipped, the clay passing through a special pug mill, then into a trough where caustic soda was added to deflocculate it. Thence it passed into large settling tanks and into troughs where the fine sand settled out. The fine clay and water then went into a large tank where alum was added again to deflocculate the clay. The precipitated slip then passed into filter presses and driers and was ready for shipment. The annual production was about 7500 tons.

The shafts ranged from 45 to 116 feet deep. In one, a drift from the shaft bottom cutting southeast passed through the tilted strata as follows: 20 feet black clay, 50 feet No. 2 gray clay, 30 to 36 feet No. 1 white clay. Overlying the white clay is the hanging wall of Oriskany sandstone.

Tests made on the clay are as follows:

	°C	Absorption (percent)	Porosity (percent)	Color
Washed clay -----	1150	1	5.9	Buff
	1300	0	0.4	Gray-buff
Second grade crude ----	1150	8.6	21.9	Buff
	1300	0	0.5	Gray-buff

The air shrinkage was 3.42 percent; at cone 8 (1290° C) linear shrinkage 11.97 percent, absorption 0, color grayish white; at cone 15 (1430° C) it was overfired.

The last name for the company was the Blue Ridge Clay Co. At present (1940) the buildings are practically demolished and the shafts are completely buried under village development.

The Mt. Eaton Clay Co. began operations west of Saylorsburg in 1917, later becoming the Pennsylvania White Clay Mining Co. Their mines and plant were located 1½ miles southwest of Saylorsburg on the north slope of Chestnut Ridge. Their original shaft was 100 feet deep, sunk in sandy flint. A 200-foot crosscut driven off at the 85-foot level passed through the following dipping strata:

Feet	
50	gray sandy clay
10	good gray clay
60	gray sandy clay
6	good white clay
6	clay with flint
15-18	No. 1 white clay, mined
51	gray clay to hanging wall of heavy sandstone

In 1922 two new shafts had been dug and the company was mining 50 tons of clay per day. The clay was ground and sold as a semi-refractory clay for foundry, blast furnace, and general metallurgical practice. Washing was abandoned as the yield was only about 25 percent. Two analyses of the clay are as follows:

	<i>Sample 1</i>	<i>Sample 2</i>
SiO ₂	69.85	67.89
Al ₂ O ₃	22.53	21.57
Fe ₂ O ₃	1.23	1.60
CaO	1.17	0.78
MgO	0.35	0.50
Alk.	1.06	1.00
TiO ₂	—	1.90
Moisture and undetermined	3.90	4.76

This company is no longer in operation.

Operations began at Kunkletown 50 years ago with the discovery of white clay on the north side of the ridge. It was first used in soap manufacture. Later the New York and Pennsylvania Brick and Tile Co. and still later the Chestnut Ridge White Clay Co. made white brick at Kunkletown. The following tests on the Kunkletown clays are given in U. S. Geological Survey Bulletin 708.

Crude clay from bottom of old pit showed 16.6 percent absorption at 1150° C. and 2.6 percent absorption at 1300° C. Another test of the crude clay showed at 1150° C. absorption 12.0, porosity 27.5 and a buff color. At 1300° C. it burned gray and showed no absorption or porosity.

Tests from the Pennsylvania Geological Survey, in percent, were as follows:

Sample	Air shrinkage	Cone 8 (1290° C)		Color	Cone 15 (1430° C)		Color
		Linear fire shrinkage	Absorption		Linear fire shrinkage	Absorption	
1	2.84	3.41	9.7	Cream	6.57	9.2	Buff
2	2.26	12.42	0	Gray-white	Overfired	.8	
3	3.42	11.97	0	Gray-white	Overfired	—	

It will thus be seen that a great deal of white and light-gray clay has been mined in the Saylorsburg-Kunkletown region and that it has been used for a wide range of purposes. How much good clay still remains along the ridge is problematical but if new deposits can be found some of the various industries might be revived.

Since the above description of the Saylorsburg-Kunkletown deposits appeared in 1934, additional stratigraphic studies have been made of the Devonian of Monroe County by F. M. Swartz.¹ The white clays

¹ The Devonian of Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. G 19, pp. 56-59, 1939.

near Kunkletown are believed now to have been derived from chert beds of New Scotland age. The similar white clays near Saylorsburg were formed from the Bowmansville chert, which lies just above the true Oriskany, and below the Onondaga beds.

South of the Oriskany and Helderberg ridges is a belt of Clinton (Bloomsburg) shales flanking Kittatinny Mountain. An outcrop of these red and green shales was sampled one mile south of Saylorsburg along the highway. This sample, no. 337, shows fairly good plasticity and a low green strength. It fires pink to brown with a firing range from 1100° to 1150° C. From the tests it would appear to be a brick shale of poor quality.

Physical tests made on Bloomsburg shales one mile south of Saylorsburg, sample 337, follow:

Water of plasticity	21.3	percent
Linear drying shrinkage	.8	percent
Time of slaking	3	minutes
Modulus of rupture	27	pounds per sq. in.
Maximum linear burning shrinkage	6.0	at cone 1
Fusion point		cone 11
Best burning range		cones 02 to 1
Firing color		pink to brown
Uses		a poor brick clay

The chemical analysis of sample 337 shows, in percent:

Ign	4.44	Al ₂ O ₃	16.80	Na ₂ O	2.12
SiO ₂	64.46	CaO	.09	MnO	.03
Fe ₂ O ₃	6.52	MgO	2.81	P ₂ O ₅	.34
TiO ₂	.51	K ₂ O	2.03	SO ₃	.37

Summarizing the clays of the county it would seem that brick-making shales could be found in the Catskill series, rather poor shales within the Middle Devonian areas; excellent residual white clays in the Oriskany ridges and rather poor shales in the Bloomsburg belt.

Selected references to the geology of Monroe County:

Leighton, H., The white clays of Pennsylvania: Pennsylvania Topog. & Geol. Survey, Bull. 112, pp. 17-19, 1934.

Peck, F. B., High grade clays of the eastern United States: U. S. Geol. Survey, Bull. 708, pp. 109-115, 1922.

Peck, F. B., White clay deposits at Saylorsburg, Monroe County, Pa.: Pennsylvania Topog. & Geol. Survey, Bull. 40, 1922.

White, I. C., The geology of Pike and Monroe counties: Pennsylvania Second Geol. Survey, Report G6, 1882.

MONTGOMERY COUNTY

Montgomery County is near the southeast corner of the State between Bucks and Chester Counties and bordered on the southeast by Philadelphia County. It lies entirely within the Piedmont Province and the northern two-thirds of it in the Triassic Lowland section. The southern portion includes the eastern end of the Chester Valley bordered by the North Valley Hills and South Valley Hills.

From the northern border of the county south to Norristown the county is underlain by the gently dipping shales and sandstones of the Newark series of the Upper Triassic, intruded by dikes and sills of diabase. This area is crossed by low ridges or uplands in belts representing the harder portions of the sediments or the larger sills. In general, however, it is a low rolling plain. The Newark series consists of the Brunswick shales 12,000 feet thick; a middle division, the Lockatong, 3,500 feet thick; and a lower division, the Stockton, 3,500 feet thick. The Brunswick has the most soft red shale suitable for brick making, although the other divisions may carry suitable shales. The Brunswick division underlies the northern half of the county, and the Lockatong and Stockton cross the middle of the county in northeast-southwest bands.

The following brickyards are in operation within the Triassic area: Florey's Brick Works at Fairview Village, the Lansdale Brick Products Company at Lansdale, and the Norristown Brick Company at Norristown. These yards use the softer Triassic shales. The Keller-Whilldin Pottery Company is located at North Wales, the Franklin Tile Company at Lansdale, and Rogers and Company plant at Royersford. The Keller-Whilldin Pottery Company uses about equal parts of Maryland clay and local residual clay from the Triassic red beds at North Wales. Rogers and Company use clays from Maryland and New Jersey. Florey's Brick Works at Fairview Village uses surface clays over the Triassic shales and makes common building brick, sand molded, and burned in Dutch kilns. The Franklin Tile Company makes floor and wall tile but uses no local clay. It uses small amounts of clay from Cumberland and Adams Counties, but most of the clay is brought from other States.

The Lansdale Brick Products Company operates a modern face brick plant at Lansdale, and uses Triassic red shale of the Brunswick formation taken from their property of 76 acres. The yard has 5 beehive kilns and can make 7,000,000 brick a year. The product is smooth or rough texture face brick, common brick, and sewer brick.

The Joseph S. Garber Brick Company many years ago made red brick from the Brunswick shales east of Pottstown. The Robinson

Clay Products Company is erecting a large plant at Pottstown to make vitrified clay tile and other ceramic products.

Many suitable sites are available, especially in the Brunswick shale or northern portion of the county.

South of the Triassic Lowland a narrow syncline of Cambrian and Ordovician strata enters the county from the west between Norristown and Conshohocken and extends in a northeast direction to the Bucks County line between Byberry and Somerton. This is the eastern end of the Chester Valley. The lower limestone portion of it extends to about Rubicum and the higher rim of Cambrian quartzites and pre-Cambrian gneisses and schists borders the valley on both north and south, and beyond Rubicum unites into a higher area of crystalline rocks. The limestone in the valley bottom is covered in many places with the usual plastic yellow residual clay which, although in small pockets, may have some ceramic uses.

In the Chester Valley there are some small outliers of the Cretaceous Patapsco clays of the Coastal Plain. These clays are up to 40 feet thick and are ferruginous, highly colored, and plastic. Such clays occur north of Swedeland, west of Plymouth Meeting, near Spring Mill, in various patches west of Conshohocken nearly to Valley Forge, and in the eastern end of the valley west of Rubicum.

In 1909 these clays were being used in the manufacture of fire brick, furnace lining, terra cotta, and pottery, especially near Spring Mill and Harmarville. At present (1940) they are not being used. Presumably the better pockets have long been exhausted.

The Cambrian quartzites on the south rim of Chester Valley tend to form low ridges. Some of the more sericitic and arkosic beds yield a kaolinitic sand but not a true clay.

The gneisses and schists south of the valley and extending into Philadelphia seem to carry little residual clay. There are, however, terrace clays of sedimentary origin, perhaps in part residual. Florey's Brick Works at Roslyn uses such a surface clay, making common building brick, sand molded and burned in Dutch kilns.

Selected references to the geology of Montgomery County:

Bascom, F. (et al.), U. S. Geol. Survey Geol. Atlas, Philadelphia folio (no. 162), 1909.

Bascom, F. (et al.), Geology and mineral resources of the Quakertown-Doylestown district, Pennsylvania and New Jersey: U. S. Geol. Survey, Bull. 828, 1931.

Bascom, F. and Stose, G. W., Geology and mineral resources of the Honeybrook and Phoenixville quadrangles, Pennsylvania: U. S. Geol. Survey, Bull. 891, 1938.

MONTOUR COUNTY

Montour County lies between Northumberland and Columbia Counties in the Ridge and Valley section east of the central part of the State. There are no high mountains within the county and its surface should be classed as low rolling to hilly. Its northern portion is drained westward by Chillisquaque Creek and its southern half is drained by the North Branch of the Susquehanna River which forms a part of the southern boundary. One township, Mayberry, lies south of the river. The sedimentary rocks exposed range from the Catskill of the Upper Devonian to the Bloomsburg of Middle Silurian. The Catskill beds are sandstones and reddish shales. They appear along the Susquehanna River east of Danville and underlie much of Mayberry Township. They are chiefly sandstones but there are some softer shale beds from which brick might be made.

The southern tip of Mayberry Township is underlain by Middle Devonian gray shales and sandstones and these appear also in a narrow belt east from Danville along the Delaware, Lackawanna & Western Railroad. Some of the softer gray shales might be developed.

Just north of this belt a ridge of Helderberg limestone and Shriver chert extends from just north of Danville east across the county. This is the south limb of an anticline and to the north lies a wide valley underlain by the Bloomsburg red shales, excellent for brick making. These may be seen 2 to 3 miles west of Danville on Route 11, and might also be developed on the Reading Railroad north from Danville to Mooresburg. The belt of shales extends from the southwestern corner of the county to and beyond Bloomsburg.

East and west from Mooresburg a second ridge of Helderberg limestone and Oriskany beds crosses the county as the north limb of the anticline. Beyond it a wide expanse of Middle Devonian sandstones and shales extends to the north county line. These beds, therefore, underlie most of the county. They are generally interlaminated sandstones and gray shales but among them are some shale beds thick enough to be worked for brick making. Along the western border the eastern end of an anticline entering the county brings in a loop of Helderberg limestone near Washingtonville. It encloses an area of the Bloomsburg red beds which should yield good brick shales, as they do to the west at Watsontown where good brick are made.

There are no brickyards in the county in 1940. The best shales would no doubt be those in the two lowlands underlain by the Bloomsburg red shales.

Selected references to the geology of Montour County:

Miller, B. L., *The Limestones of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 20*, 1934.

White, I. C., The geology of the Susquehanna River Region in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour and Northumberland: Pennsylvania Second Geol. Survey, vol. G 7, 1883.

Willard, B., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

NORTHAMPTON COUNTY

The geology of Northampton County has recently been described most thoroughly by B. L. Miller. The greater part of the description of the geology and clay resources which follows has been taken from that report (Pennsylvania Geol. Survey, Bull. C 48). Northampton County lies along the eastern border of the State, its eastern boundary being the Delaware River. Its principal cities are Bethlehem and Easton. For years it has been one of the most important counties in the United States in the production of portland cement and slate. From a physiographic standpoint the county is divided into a northern mountain boundary, a main area of lowland, and a southern mountainous belt.

The northern border is a high sharp ridge, Kittatinny Mountain, rising 1,400 to 1,600 feet above sea level. This ridge is made up of steeply dipping Silurian sandstones and conglomerates and is the most southern of the ridges of the Ridge and Valley province.

South of Kittatinny Mountain and making up the greater part of the county is a broad area of lowlands, a part of the Appalachian Valley section. The northern half of the lowland, a belt 6 to 9 miles wide, is underlain by Upper Ordovician shales and slates and is known as the slate belt. It is a rolling plateau with hill tops 600 to 800 feet above sea level. The southern half of the valley is underlain by Cambrian and Ordovician limestones, dolomites, and some quartzite. Its surface is flatter than the slate belt and stands at 400 feet above the sea.

South of the Great Valley a wide belt of hills or mountains rises to 700 to 1,000 feet above sea level and constitutes the South Mountains, Reading or Durham Hills, Lehigh Mountain, or the Reading Prong of the New England uplands. These mountains are formed chiefly of pre-Cambrian crystalline rocks with smaller intervening valleys of Paleozoic limestone. They form the main southern boundary of the county with the exception of some Triassic conglomerates which make Flint Hill.

The clays of the county are derived from four sources, residual clays, Paleozoic shales, glacial clays, and recent alluvium.

In Kittatinny Mountain there are no important clays. Soft Bloomsburg red shales flank the mountain on the north, but its

southern slope in Northampton County is made up of resistant sandstone and conglomerate. Glacial clays are also thin or absent and could yield little clay.

Slate belt. The slate belt is underlain by folded Martinsburg shales, sandy shales, and slates of Upper Ordovician age. Much of this material is metamorphosed into true slate but certain portions of it among its lower members and toward the western end of the belt are softer, and where well weathered might have sufficient plasticity to be of value. In Berks County the Martinsburg shales are made into brick. In Northampton County none of them are used in brick making. Glacial clays are also common over the slate belt and the better pockets of them might be used.

Limestone valley. In the limestone valley the following general section is found.

Ordovician	Feet
Jacksonburg formation	700 slaty cement rock, cement limestone
Beekmantown formation	1200 chiefly dolomites
Cambrian	
Allentown formation	1500 limestones
Tomstown formation	700 dolomitic limestones
Hardyston formation	150 arkosic quartzites

None of these formations carry enough shale to be of value. The Tomstown carries thin beds of sericitic shale but not over 10 feet in thickness and usually much less. The Hardyston quartzites have small shaly lenses only. The Jacksonburg limestones carry thin beds of bentonite but the thickest bed is only 13 inches and most of them only a few inches.

The residual clays formed by the long decay of the limestones or the shaly lenses in the Hardyston furnish the chief source of clay in the valley. The limestone yields a yellow to red, very plastic residual clay in irregular shallow pockets. Much of this, however, was removed during the ice advance in the glacial period or else became mixed with the glacial clay and boulders. This clay is irregular in occurrence, and somewhat stony, but can be used in making red brick, tile, stoneware, flower pots, and types of art pottery. The clay associated with the Hardyston quartzite has been formed by the decay of arkosic (feldspathic) portions of the quartzite and by decay of shaly lenses. It occurs in irregular pockets and is vari-colored, white, red, purple, black, and other colors. These clays have generally been uncovered in the past in prospecting for residual limonite iron ores with which they are often associated. During the mining operations much of this clay was exposed and during the washing of the

ore much of the clay was impounded in basins or mud dams. Some of the mud-dam deposits have been used in brick making. Clays available in the valley are, therefore, of four types: residual limestone clay, residual quartzite clay, mud-dam clay, and glacial clay.

In 1939 three brickyards were operating in the county and all were using one or more of these types of clay. The Zehnder Brick Company has a brickyard in South Easton. Their clay is a limestone residual clay reworked by glacial ice so that it now contains glacial clay and boulders. The clay pit is 50 feet deep and the clay is taken out with a drag line bucket. The brick are burned in three Dutch kilns, each of 300,000 brick capacity. The product is deep red brick. The Zehnder brickyard was not operated in 1940.

The Nazareth Face Brick Company operates $1\frac{1}{2}$ miles southwest of Nazareth, using glacial clay in part stratified by water action, and containing boulders and sand and gravel lenses. The maximum thickness is 60 feet but the present pit has a 20-foot face. The clay is dug with steam shovel, carried by incline to the plant, where it is screened and put through a clay-batting machine to further separate the stony particles from the clay. It then goes to electrically heated screens. The brick are molded in an auger machine, wire cut, and dried in waste-heat driers. Burning is done in two rectangular and six beehive kilns, each of 80,000 capacity. The product is red face brick. This was the only brick plant operated in the county in 1940.

The third brick plant is that of the Saucon Valley Brick Company half a mile west of Bingen. In former years the company used mud-dam clays from the washing operations of the old Bahl iron ore mine. In recent years and at present (1938) the clay used is a mixture of residual and glacial clay from a pit one-quarter of a mile northwest of the plant. The working face is 15 to 18 feet high. The clay is dug with a steam shovel and trucked to the plant. It is dumped into a hopper with bars across the bottom to remove the larger cobbles. It then passes through rolls set to eliminate smaller pebbles and finally goes to smooth rolls which crush the clay and finer rock fragments. Molding is done by auger machine, and the brick are dried in waste-heat driers. Burning is done in 4 coal-fired kilns of 100,000 brick capacity each. Red brick is the product. This company discontinued operations and scrapped the plant in 1940.

No other use has been made of the residual clays but by careful selection white and other colors might be taken out in small quantity and put to special uses such as in art pottery, colored tiles, linoleum, etc. The following analyses of the clays associated with limonite ore in the Wharton mine, two miles southeast of Hellertown, are taken from Bulletin C 48. No. 1 is common clay, No. 2 is white clay, and No. 3 is yellow clay.

Analyses of clays from Wharton iron mine

	1	2	3
Silica	49.13	72.16	64.56
Alumina	33.87	21.76	22.77
Ferric oxide	3.04	.99	5.63
Lime	.12	.22	.40
Magnesia	.98	.69	1.28
Soda	.52	2.12	2.80
Potash	.63	3.02	3.85
Titanic acid	.19		
Water	11.50	4.75	4.67

The South Mountain crystalline rocks produce a residual kaolinitic sand from the lighter gneisses. This apparently is more siliceous than kaolinitic and is used as a foundry sand and a building sand. There are many pits of this on the ridge near Bethlehem and Hellertown. There might be portions of this residual from which kaolin could be washed but as far as known no such clays have been found.

Selected references to the geology of Northampton County:

- Behre, C. H., Jr., Slate in Northampton County, Pa.: Pennsylvania Topog. and Geol. Survey, Bull. M 9, 1927.
- Behre, C. H., Jr., Slate in Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 16, 1933.
- Lesley, J. P. (et al.), The geology of Lehigh and Northampton Counties: Pennsylvania Second Geol. Survey, Report D 3, vol. 1, 1883.
- Leverett, Frank, Glacial deposits outside the Wisconsin Terminal Moraine in Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 7, 1934.
- Miller, B. L., Limestones of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. M 20, 1934.
- Miller, B. L. (with Frazer, D. M. and Miller, R. L.), Northampton County, Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. C 48, 1939. Contains a very extensive bibliography of the geology of the county.
- Ward, Freeman, Recent geological history of the Delaware Valley below the Water Gap: Pennsylvania Topog. and Geol. Survey, Bull. G 10, 1938.

NORTHUMBERLAND COUNTY

Northumberland County is bordered on the west by Susquehanna River and on the east by Montour and Columbia Counties. It lies within the Ridge and Valley section of the Appalachian Valley province, the axis of the folds trending nearly east-west. This breaks the county into a close series of ridges and valleys with the Susquehanna River crossing them at right angles, exposing the structures excellently. The exposed strata range from the Clinton shales of the Silurian up to the Pennsylvanian Coal Measures.

The Clinton shales appear in two eroded anticlinal areas in the northern half of the county; one area is along the river through

Watsonstown and Milton and extending east 5 to 10 miles to the Montour County line; the other along the river above and below Chillisquaque and extending east into Montour County north of Danville. Much of the Clinton is soft, vari-colored shale and from it excellent brick are made, as proven in the brickyards at Watsonstown and by tests in Juniata County. Care must be taken to avoid limy layers and shales too calcareous.

At Watsonstown, the Keystone Brick Company made common and face brick at the north end of the borough from yellow and red Clinton shale. Operations stopped in 1935. The Watsonstown Brick Company uses red Clinton shales dug at the plant built in 1908 one mile south of Watsonstown and 500 feet east of the Susquehanna River. The equipment consists of an electric shovel, a single roll crusher, four 9-foot dry pans, pug mill and a stiff-mud brick machine, and 8 rectangular, down-draft kilns, each with capacities of 150,000 brick. They make common and red face brick, vitrified acid brick, and paving block, and crushed fine material from red bats for drive-ways and tennis courts.

The Ferro Brick Company, which made building brick just south of the Watsonstown Brick Company plant, stopped operating in 1931.

The Fiske Brick & Granule Company, which made granules but no brick, sold its plant two miles south of Watsonstown to the Funkhouser Company, Hagerstown, Maryland, in 1940, probably to be used for burning Clinton shale to clinker and crushing for red roofing granules.

The shales of the Chemung, Portage, Genesee, Hamilton, and Marcellus divisions of the Devonian cover the greater part of the county in five wide belts. North of the junction of the two branches of the Susquehanna there are three wide belts of these Devonian shales alternating with the two belts of Clinton shales. A sample was taken of a very extensive cliff of rather pure shale, probably Hamilton formation, two miles north of Northumberland (sample 300). This shows good plasticity and fair green strength. It fires salmon to dark red brown with a firing range from 1,100° to 1,200° C. It could be used in making brick, hollow tile, or drain tile. Some of the Devonian shales are interlaminated with thin sandstone layers but this cliff demonstrates that areas of good brick shales in accessible position may be found.

Below Sunbury the Susquehanna cuts through Devonian shales nearly all the way to Dalmatia, exposing much seemingly good shale. Three bands of Catskill red shales cross the county, one east from Northumberland, another north of Little Mountain, and the third south of Line Mountain. These latter unite between Fishers Ferry and Herndon. The Catskill red beds carry soft red shales and reddish sandstone layers. Brick may be made from the softer shales.

The western end of the Western Middle Anthracite Basin enters southeastern Northumberland County as a narrow synclinal valley of lower Pennsylvanian slates and anthracite beds surrounded by a high rim made up of resistant Pottsville and Pocono sandstones separated by soft red Mauch Chunk shales. Some of the soft Mauch Chunk may be suitable for brick making.

The shales in the coal basin are too slaty and too carbonaceous to be of much value unless special slow-burning methods should be employed. There are no fire clays accompanying the anthracite beds.

The two important brick shales are thus the Clinton and the Hamilton and both are readily obtained along the Susquehanna River.

Physical tests of the one sample (no. 300) collected in the county show:

Water of plasticity	22.9 percent
Linear drying shrinkage	5.4 percent
Time of slaking	4 minutes
Modulus of rupture	131 pounds per sq. inch
Maximum linear burning shrinkage	5.7 percent at cone 1
Fusion point	Cone 14
Best burning range	Cones 02 to 4
Firing color	Salmon to dark brown
Suggested uses	Brick, hollow tile, drain tile

Its chemical analysis is as follows:

Ignition ... 6.23	TiO ₂ 1.07	MgO 1.27	MnO07
SiO ₂ 55.42	Al ₂ O ₃ 21.35	K ₂ O 1.05	P ₂ O ₅
Fe ₂ O ₃ 7.28	CaO29	Na ₂ O 1.26	SO ₃54

The chief book of reference to the geology of Northumberland County is: White, I. C., The Geology of the Susquehanna River in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour and Northumberland. Pennsylvania Second Geological Survey, vol. G 7, 1883.

PERRY COUNTY

Perry County lies between Juniata and Cumberland Counties with the Susquehanna River forming its eastern boundary from a point north of Liverpool to a point south of Marysville. The Juniata River also crosses the eastern section from Millerstown to Amity Hall. Highways and railroads follow these rivers. Other highways traverse the county from west to east following the valleys chiefly in areas of Middle Silurian shales.

The north, west and southern boundaries of the county are high wooded sandstone ridges of the Lower Silurian Tuscarora sandstone, dipping in toward the center of the county in a great spoon-shaped

syncline. On the north is Tuscarora Mountain, on the south is First, Blue, Kittatinny, or North Mountain.

In the northwestern corner an anticline brings up a small area of Ordovician shale and limestone, the oldest exposed strata in the county. The rest of the county is underlain by Silurian, Devonian, and Mississippian strata. The ridge-forming sandstones are the Tuscarora of the Silurian, Oriskany, Montebello and Trimmers Rock of the Devonian, and the Pocono of the Mississippian.

The intervening shales form the valley areas and these are the source of brick-making materials. Those of most importance are the Clinton shales of Silurian age; the Mahantango shales of the upper Hamilton, some of the Portage shales and the thick red shales of the Catskill division of the Devonian; and the soft red shales of the Mauch Chunk division of the Mississippian.

The Clinton shales are soft and vari-colored. Samples were taken of them in Juniata County (315-318) and it was found that they are of good quality for red brick. They are available in the lowlands at the foot of Tuscarora Mountain and Kittatinny (Blue) Mountain and over a large area in western Perry County. The highways from New Germantown to Blain, Millerstown and Liverpool and from Blain to Loysville, Landisburg, and New Bloomfield lie chiefly on Clinton shales, and the railroad from New Germantown east to New Bloomfield is also in these shales. Being available also near Millerstown and near Marysville they, therefore, constitute the chief potential source of brick shales in the western half of the county and along the north and south borders.

The Middle Devonian strata are in part too dark and fissile for brick making and in part too sandy. The most promising shale is the Mahantango division of the Hamilton, a gray to brown, non-fissile shale. In some places, however, the shale is largely displaced by heavy sandstones. The middle divisions of the Devonian with their shales and sandstones crop out along the Susquehanna River near Marysville, again in an area south of Montgomery Ferry, and in a third belt north of Liverpool.

Along the Juniata River they may be seen from Newport south for 5 miles (with some Catskill red beds also appearing), and again a mile or two south of Millerstown. East from New Bloomfield for 5 miles the railroad lies mostly on these Devonian shales. They are thus accessible for brick making along highways and rail lines.

The Catskill division of the Upper Devonian is composed of soft red shales and sandstones. Much of this is sandy but by careful selection brick shales might be obtained. Its outcrops cross the Susquehanna River north of Marysville, a wide belt north from Duncannon, through and beyond New Buffalo, and a third belt at

Liverpool. Up the Juniata the Catskill red beds are seen near Amity Hall and several miles north, and again in the vicinity of Newport.

The Mauch Chunk series is chiefly made up of soft red clay shales of good quality for brick manufacture. They are available along the Susquehanna River in two areas; first, in the center of a syncline between Second and Peters Mountains between Dauphin and Duncannon, and second, in a syncline between Berry and Mahantango Mountains along the river opposite Millersburg, Dauphin County. Both areas have accessible locations for brickyards.

According to J. W. Sheibley, of Landisburg, some of the early settlers built houses of brick made by hand on the spot. An example is the Wagner house one mile east of Alinda near Spring Dale School. Two brickyards formerly operated in the county. The Brunner yard at the road forks on Trout Run 1 mile west of Route 34 on the south side of Mahanoy Ridge and $1\frac{3}{4}$ miles from New Bloomfield was longest in operation. Common brick were made from clay and shale at or near the contact of the Hamilton and Marcellus beds. Production ceased early in this century. The Fleurie brickyard at Landisburg made common brick from residual Helderberg clay and alluvium prior to 1915.

Mr. Sheibley recalls also that at least four potteries in former years produced stoneware, mostly jugs and crocks, from local clay. They were the Updegraffe pottery at Warm Spring (1838), Offener pottery at Landisburg, Frank pottery at Newport, and Enterline pottery at Bridgeport. The Frank pottery is remembered for its side line of stoneware dogs, frogs, and other figures for yard ornaments and door stops. The Enterline pottery $1\frac{1}{2}$ miles south of Landisburg specialized in jugs because there was a distillery at Bridgeport.

No use is now made of clays or shales of the county but from experience with the Silurian, Devonian, and Mississippian shales in adjoining counties it would seem that much suitable material is at hand.

Selected references to the geology of Perry County:

Claypole, E. W., A preliminary report on the Paleontology of Perry County: Pennsylvania Second Geol. Survey, Report F 2, 1885.

Willard, B., (Swartz, F. M. and Cleaves, A. B.), The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

PHILADELPHIA COUNTY

Philadelphia is a small but very important county. It lies along Delaware River in the southeastern corner of the State. Philadelphia city is coextensive with the county.

The northwestern two-thirds of the county is a part of the Piedmont Province and is underlain by schist and gneiss and other metamorphic and igneous rocks of pre-Cambrian age. Its surface stands from 200 to 400 feet above sea level in the higher portions but slopes gradually toward the Delaware River. Some patches of surface clay of residual origin occur in this province but there is little clay of value.

The southwestern third of the county, a belt 8 to 10 miles in width, fringes the north side of the Delaware River. This is the inner edge of the Coastal Plain which stretches out over New Jersey. The Pennsylvania portion of the plain rises from sea level to heights of over a hundred feet. It is underlain by thin deposits of the Pensauken and Cape May sands and gravels of the Quaternary system. These are underlain by the crystalline schists of the Piedmont and the covering is so slight that schists are exposed over much of the plain, in some places nearly down to the Delaware River.

No areas of the excellent Cretaceous clays of the Coastal Plain occur in the county although there are a few areas of the Paptasco clays in Montgomery County.

The Pensauken and Cape May formations contain practically no clay.

There are, however, at various points on the Coastal Plain, beds of clay that are residual from the nearby or underlying pre-Cambrian rocks. These lie at elevations from 20 to 100 feet above sea level and have been worked for many years as a source of brick clay. The clay is plastic, not very stony and occurs in pockets 5 to 30 feet deep. In earlier days nearly all brick used in Philadelphia were produced by small plants using these clays for common red brick. Larger plants in other parts of the State, manufacturing shale brick as face brick, have taken over much of the market. There are now (1940) in the county only two brick plants using local clays, Wm. Conway, Inc., 5800 Walnut Street, in Philadelphia and Hamilton & Kelly, Inc. (The Keystone Brick Co.), Tabor and Godfrey Avenue, Philadelphia.

Hamilton and Kelly, Inc., trading as the Keystone Brick Company, manufacture common red building brick from surface clays ranging from one foot to twelve feet in thickness. The clay is dug with two electric power shovels and transported by gasoline locomotives hauling side dump cars. The clay is passed through Chambers Bros. dis-

integrator, pug mill, and stiff mud machines, electrically driven. The brick are dried on cars fitted with steam coils.

The plant of the Philadelphia Brick Company lies just over the Delaware County line in Sharon Hill. (See Delaware County.)

In past years brick have been made near Frankford, Nicetown, Point Breeze, and between Angora and Haddington.

There are many other ceramic plants in and around Philadelphia but they manufacture fire brick, terra cotta, porcelain, and other special products from the very fine clays of New Jersey and other States, using only small amounts of Pennsylvania clay.

Wm. Conway, Inc., makes common red building brick from a deposit of surface clay 5 feet deep, which is dug with a gasoline shovel. The mill is operated by steam. Brick are burned in a Haigh continuous kiln. The capacity of the plant is 12,000,000 brick per year.

Selected references to the geology of Philadelphia County:

Bascom, F. (et al.), U. S. Geol. Survey Geol. Atlas, Philadelphia folio (no. 162), 1909.

Hall, C. E., Report on Philadelphia and the southern parts of Montgomery and Bucks Counties: Pennsylvania Second Geol. Survey, vol. C 6, 1882.

PIKE COUNTY

Pike County borders on New York and New Jersey in the north-eastern corner of the State. Most of it is part of the great Pocono Plateau. At the eastern edge of this plateau an escarpment leads down to the valley of the Delaware River.

The plateau, according to Willard, is made up of Catskill and Chemung red shales and sandstones, with small amounts of greenish and gray beds. Among these beds careful selection would no doubt yield some softer shales which could be used in brick making. None are used at present, because the county is mostly forested and sparsely settled.

East of a broad belt of Delaware River flags of Portage age is the escarpment down through the Devonian strata to the Marcellus and Onondaga divisions. These beds are usually very sandy and show little promise of yielding brick shales. Along the Delaware River the softer, generally dark gray shales belong to the Marcellus division of the Devonian.

Samples of the Marcellus shales were taken along the river highway south of Milford. Sample 335 is a dark blue-gray sandy shale exposed in a bank one mile south of Milford. It shows fairly good plasticity and low green strength. It burns salmon to brown with a

burning range from 1,100° to 1,150° C. It seems suited to the manufacture of face brick, perhaps somewhat low grade.

Sample 336 is of the Marcellus shale making a 50-foot bank along the river highway three miles south of Milford. This shale shows fairly good plasticity and low green strength. It burns to a salmon to good brick red with a burning range from 1,050° C to 1,150° C. It is suited to the making of low-grade face brick.

Just south of Dingmans Ferry more, and possibly softer, shale is exposed. It is evident that there is a quantity of very accessible shale along the river and tests would indicate that at least low-grade face brick can be manufactured.

Physical tests of Pike County clays

Sample number	Percent water of plasticity	Percent linear (drying shrinkage)	Time of slaking (in minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point at cone	Best burning range (cones)	Firing color	Suggested uses
335	19.5	3.5	5	36	3.9	1	14	02-1	Salmon to brown	Common or face brick
336	18.8	3.9	7	36	5.3	02	14	05-1	Salmon to brick red	Common or face brick

Chemical analysis was made of sample 336, as follows:

Ign	4.39	Fe ₂ O ₃	8.26	Al ₂ O ₃	15.78
SiO ₂	67.74	TiO ₂	.62	CaO	.52

References to the geology of Pike County:

White, I. C., The geology of Pike and Monroe Counties: Pennsylvania Second Geol. Survey, Report G 6, 1882.

Willard, Bradford, et al., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

POTTER COUNTY

Potter County lies east of McKean County along the border of New York State in the high, wooded plateau area of northern Pennsylvania, dissected by deep valleys. The strata are gently folded into a series of anticlines and synclines trending northeast-southwest. Erosion of the folded strata has brought about the distribution of outcrops in parallel northeast bands, the lowlands in the anticlinal areas exposing Upper Devonian beds and the higher lands being underlain by synclinal basins of Pottsville strata. The general succession of strata shows:

Pennsylvanian	
Allegheny group—one small area in west	
Pottsville series	260-300 feet
Devonian	
Oswayo group	1,000 feet
Cattaraugus group	500 “
Chemung group	600 “

The Pottsville beds are chiefly heavy sandstones and conglomerates but they carry thin coals of Mercer and Sharon age and with these coals there are thin fire clays which may be of value.

The Oswayo is made up of gray to greenish shales and thin sandstones. The Cattaraugus is the more shaly of the formations and is generally a red shale with some reddish and greenish sandstones. It is the typical bright red series, generally known as the Catskill red beds. One sample (184) was taken of this shale from a road cut east of Galeton. This proved to be of poor quality for ceramic use, having very poor burning qualities. It showed poor plasticity and low green strength. It fired from light red to black but with no satisfactory burning range.

Water of plasticity	18.1 percent
Time of slaking	8 minutes
Fusion point at cone	12
Linear drying shrinkage	6.2 percent
Showed expansion during burning.	
Modulus of rupture—45 pounds per square inch.	

It chemical analysis showed:

Ign	3.67	TiO ₂	1.40	MgO	.60	MnO	.05
SiO ₂	59.00	Al ₂ O ₃	21.25	K ₂ O	1.65	P ₂ O ₅	.20
Fe ₂ O ₃	9.50	CaO	.90	Na ₂ O	1.69	SO ₃	.30

The Chemung group consists chiefly of gray shales and thin sandstones. No promising outcrops of accessible shale were seen in the county but there seems no doubt that careful search would bring to

light shales of the quality of those successfully used in McKean County.

Glacial clays should be found in the northeastern corner of the county and the more plastic of these might be made into brick as has been done in Westfield in Tioga County.

Selected references to the geology of Potter County:

Fuller, M. L., U. S. Geol. Survey Geol. Atlas, Gaines folio (no. 92), 1903.

Sherwood, A. (with F. Platt), The Geology of Potter County: Penna. Second Geol. Survey, vol. G 3, 1880.

SCHUYLKILL COUNTY

Schuykill County lies in the east-central part of the State north of Berks County. It is wholly within the Ridge and Valley section, with Kittatinny Mountain its southern boundary.

The strata exposed range in age from Pennsylvanian in the anthracite basins to Lower Silurian sandstones in Kittatinny Mountain. The northern half of the county is underlain chiefly by Mauch Chunk, Pottsville, and Allegheny strata in several synclinal coal basins; the southern portion is an anticlinal area of Devonian and Silurian strata between Second and Kittatinny Mountains.

The Coal Measures lie in basins within rims of Pottsville sandstone. The southern basin passes across the county from Tamaqua through Pottsville. To the north is the Mahanoy Basin and on the extreme north border a few western ends of the Hazleton Basin. The Coal Measures consist of dark slates and shales, some sandstones, and many beds of anthracite. The total thickness of the series may be 2,700 feet. The shales are too dark and too slaty to be of much value in brick making and are not used.

Between the ridges of Pottsville sandstone which surround the anthracite basins and the outer rim of Pocono sandstone are lowlands underlain by soft Mauch Chunk shales 3,000 feet thick. These strata carry much good brick-making shale and are usually quite accessible. The northern area of Mauch Chunk shales covers most of the northeastern corner of the county and is crossed by the Reading Railroad north and east of Rington. A second area lies around Barnesville east of Mahanoy City; a third lies south and east of Mahantango Mountain in the western part of the county in the valley of Deep Creek and Pine Creek; a fourth area lies within a rim of Pottsville ridges in the Tower City district on the southwestern border of the county; a fifth area is a long band of Mauch Chunk which crosses the

county between Sharp Mountain on the north and Second Mountain on the south, and passes just south of Pottsville.

Beneath the Mauch Chunk formation is the Pocono sandstone which rises as a resistant ridge, Second Mountain, on the south rim of the Pottsville coal basin and as Mahantango Mountain in the western corner of the county. South of Second Mountain, the next succeeding lower formation is the Catskill series, 3,000 feet thick. Some of this is resistant sandstone and makes up the southern part of Second Mountain. Softer red shales lie within the lower portions of the belt and these might be used in brick making. More of the Catskill series is seen in the western corner of the county in Mahantango Creek valley.

South of Second Mountain and its southern fringe of Catskill red beds is a wide belt of Middle Devonian shales and sandstones 3,000 feet thick. Along the Schuylkill this band lies between Cressona and Auburn. The best shale in this Devonian area is the Mahantango shale of the Hamilton formation. The Reading Railroad follows the Devonian area from Auburn west to Pine Grove and Suedberg, and also crosses it at New Ringgold.

South of the Middle Devonian belt there are low ridges of Oriskany sandstone and Helderberg limestone passing through New Ringgold, Orwigsburg, and Auburn. Between these ridges and Kittatiny Mountain is a low belt of Middle Silurian shales. These appear in the south part of Auburn and along the Reading Railroad from Port Clinton to New Ringgold. These are the Bloomsburg red beds made up of soft red and green shale, excellent brick material. They are 1,800 feet thick.

The Bloomsburg red beds are used by one brick company, the Auburn Brick Company at Auburn. The shale is dug from an open pit by a gasoline shovel. It is passed through an American grinder and a Williams hammer mill. It is then passed over a Link-Belt vibrating screen and through a pug mill and auger machine. The brick are burned in down draft kilns fired with both anthracite and bituminous coal. The product is face brick of various textures and colors, radial chimney brick, paving block, and Auburn block.

Selected references to the geology of Schuylkill County:

A geological map of Schuylkill County, compiled from the Surveys of J. P. Lesley, C. A. Ashburner, F. A. Hill, and others. Pennsylvania Second Geol. Survey, 1891.

Swartz, C. K. (and Swartz, F. M.), Early Silurian formations of southeastern Pennsylvania: Geol. Soc. of America Bull., vol. 42, pp. 621-662, 1931.

Willard, B., Guide to the geology of the Upper Schuylkill Valley: Pennsylvania Topog. and Geol. Survey, Bull. G 14, 1939.

SNYDER COUNTY

Snyder County lies south of Union County and has the Susquehanna River for its eastern boundary. It is within the Ridge and Valley section, the folded Appalachian Mountain belt of high sandstone or quartzite ridges and lowlands of shale. Jacks Mountain, a ridge of Tuscarora (Medina) sandstones and quartzites, forms the northwestern border and Shade Mountain of similar rock projects into the county from the southwestern border.

The lower lands between these ridges and to the south of Shade Mountain are underlain by Silurian and Devonian shales, limestones, and sandstones. The Helderberg limestone, the Oriskany sandstone, and some sandstones of the Middle Devonian form subordinate ridges. The most important shales for brick making are the Middle Silurian, Clinton shales; the Middle Devonian, Hamilton shales; and the Upper Devonian, Catskill shales. Each of these has been used in adjoining counties for brick manufacture.

The Clinton shales are generally soft, vari-colored, and of good quality. They underlie a wide anticlinal area which crosses the county from the Susquehanna River at Selinsgrove west through Freeburg, Paxtonville, Richfield, and Beavertown to the southwestern corner of the county. They are accessible at Selinsgrove and along the Pennsylvania Railroad west from Selinsgrove to McClure, and along Highway 522 in the same belt. The red shales of the Clinton are used by two firms in brick manufacture.

The Hill Brick Company has a plant at Beavertown using red shale from a 15-foot quarry. The shale is pulverized in a dry pan, passed through a pug mill and stiff-mud machine, and burned in a battery of six kilns. The products are common and face brick in a range of colors from light red to black.

The Paxton Brick Company of Watsontown, Pa., has a brickyard at Paxtonville, 3 miles west of Middleburg. Common and face brick and paving block are made from red shale, using both stiff-mud and soft-mud processes, motor driven. Burning is done in a gas-fired continuous kiln of one million brick capacity. The plant has a capacity of 16,000,000 brick a year.

The Middle Devonian shales, of which the Hamilton division is usually the best, lie in a broad synclinal area along the northern half of the county from the junction of the branches of the Susquehanna west through Middleburg and Middle Creek to the southwest corner of the county. South of Shade Mountain in the southeast corner of the county is a second area of the Middle Devonian. This is well exposed along the Susquehanna River from a point below Selinsgrove down the river through Port Trevorton and McKees Half Falls to the

southeastern corner of the county. The Catskill red shales and red sandstones extend into the county from the east in two synclinal areas, the first in a narrow belt through Kratzerville, the other through Dundare. Excellent brick can be made from the softer Clinton shales.

Selected references to the geology of Snyder County:

d'Inwilliers, E. V., Report on the geology of the four counties, Union, Snyder, Mifflin and Juniata: Pennsylvania Second Geol. Survey, vol. F 3, 1891.

Willard, B. (et al.), The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

Willard, B., Guide to the geology from Dauphin to Sunbury: Pennsylvania Topog. and Geol. Survey, Bull. G 13, 1939.

SOMERSET COUNTY

Somerset County lies between Fayette and Bedford counties on the Maryland line. Laurel Hill forms the western boundary and Allegheny Mountain forms its northeastern boundary. The townships in the southeastern corner lie east of the Allegheny Mountain. Big and Little Savage Mountains and Little Allegheny Mountain rise in the extreme southeastern corner. Negro Mountain enters the county about midway along its southern border and extends as a prominent ridge as far north as the Casselman River. The mountains are wooded and are made up chiefly of the sandstones of the Pocono formation. The intervening lower lands, which make up most of the county, are largely devoted to farming and are underlain by shales of the Allegheny, Conemaugh, and in small areas, the Monongahela groups. The southern part of the county is crossed by the Baltimore & Ohio and the Western Maryland railroads, while the northern parts are served by branches of the Pennsylvania and the Baltimore & Ohio railroads. The northern half of the county is drained by Stony and Shade Creeks into the Conemaugh River; the southern half by the Casselman River into the Youghiogheny River; and the southeastern townships by Wills Creek into the Potomac River.

Southeastern Townships

Allegheny Mountain forms the eastern boundary of the county north of the Lincoln Highway. South of this highway this ridge continues its southwest course and passes into Maryland southeast of Salisbury, but the county line goes due south to Little Allegheny Mountain, which it follows to the Maryland line. Its rugged topog-

raphy sets the southeast corner apart from the rest of the county. East of the Allegheny Mountain the townships of Greenville, Larimer, Northampton, Allegheny, and the western part of Fairhope lie in an area of anticlinal structure in which Devonian rocks make up most of the surface. This valley is from 7 to 8 miles wide and includes small villages, as New Baltimore, Johnsburg, Glencoe, and Wittenburg. Some of the shales of this area are good enough to use in the manufacture of red brick or tile but many are too sandy, grading in many instances into thin-bedded sandstones. No use is made of the shales of the valley and there is little demand for brick. There are no clays of higher quality in the district.

Fairhope and Williams.—East of these townships, in Southampton and eastern Fairhope Townships, Big Savage and Little Allegheny Mountains are separated by a synclinal valley in the Wellersburg area; to the north the two ridges unite near the border of Bedford County, east of Fairhope. The ridges are made up of the resistant Pocono and Pottsville sandstones and carry little shale. In the Pottsville series, however, several horizons have yielded valuable plastic clays and flint clays. These usually lie near the top of the Pottsville strata or may belong to the lower part of the Allegheny group. The chief area of clay mining activity has been along Wills Creek, which has cut a deep gap through the northern part of the mountain in the vicinity of Fairhope and Williams. Clay mining and manufacture of fire brick were active here for over sixty years, but have been abandoned in recent years.

Early developments in the Williams area were described by Harden¹. From this report we learn that the North Savage Fire Brick Company opened a clay mine in 1881 on the land of H. T. Weld at Williams. The entry was 327 feet above the river. The section shown was as follows:

Coal	4 feet
Concealed	20 feet
Fine white sandstone	10 feet
Coal	2 to 12 inches
Flint clay or plastic clay	4 to 15 feet
Shale	5 feet
Coal	0 to 6 inches
Crossbedded sandstone	—

The strata dip 8° S.30° E. The clay bed ranged from 4 to 15 feet in thickness and was made up of varying amounts of flint and plastic clays with no regularity. When the report was written 10 to 12 feet of flint clay was showing in the headings.

¹ Lesley, J. P., and Harden, E. B.: Penna. Second Geol. Survey, Ann. Rpt. for 1885, pp. 227-249, 1886.

The Savage Fire Brick Company opened a mine on the same bed and adjoining the above in 1870, with additional openings in 1875. This clay was from a few feet up to 25 feet thick and was of about the same character as that in the other mine. These mines were on the northeast side of Wills Creek. On the south side of the creek and 245 feet above it an opening was made on the same clay bed, here about 7 feet thick and overlain by 10 inches of coal. The 4-foot bed of coal was 35 feet above the clay bed.

Shaw¹ gives the result of tests made on the clays of the Williams-Fairhope district. A sample of the flint clay from the mine of the Savage Brick Company (no. 22), fused at cone 30 and is classified as a No. 1 fire clay. A plastic clay from the same mine (no. 23) fused at cone 26½ and is classed by Shaw as a No. 3 clay. Shaw made tests on plastic clays owned by L. M. Neld and mined at Fairhope. One of these consisted of a bed of clay 20 feet thick, 17 feet soft and 3 feet flint. This clay seemed to be of low quality. Another plastic clay from the same property proved to be a No. 3 plastic clay and suitable for the manufacture of refractories, paving brick, or tile. This last clay mentioned is said to be of the Mercer horizon while Shaw classes the others as Sharon. It is apparent that there is at least one bed of plastic and flint clay of value above Wills Creek and the Baltimore & Ohio Railroad.

The North Savage Fire Brick Company operated from 1879 to 1918 and for many years manufactured high grade Savage Fire Brick. For some years before closing the operations, lack of good fire clay caused them to turn to the manufacture of paving brick from local shales. Fire brick, however, were made during the World War, from 1914 to 1918, and operations were stopped in the latter year when the plant was destroyed by fire.

The Savage Fire Brick Company operated from about 1870 through the period of the World War and had plants at Williams and at Hyndman. They have not operated for several years.

Little Allegheny Mountain.—Southwest from Williams along Little Allegheny Mountain plastic and flint clays of the Allegheny group have been mined and are described in the report of the Maryland Geological Survey². The following notes on the clays of this area are taken from this report, the locality descriptions from the article by G. M. Hall, and the tests from the pages by H. G. Schurecht. Supplemental information has been added in 1940.

Northwest of Cooks Mills and southwest of Hyndman the Cooks

¹ Shaw, J. B., Pennsylvania Topog. and Geol. Survey, Bull. M. 10, p. 27, 1928.

² Watts, A. S., et al., Maryland Geol. Survey, vol. II, pt. 2, 1922.

Mills Coal, Lumber and Fire Clay Company own clay properties on which the following section is exposed:

	Feet
Surface	4.0
Massive sandstone	6.6
Very sandy clay	4.6
Fissile black shale with plant remains	4.6
Gray shale, almost a clay	2.4
Thin to medium-bedded sandstone	12.5
Massive white sandstone, many plant impressions	5.5
Soft sandy clay with thin stained sandstone bands	3.2
Tough brown to gray flint clay	4.1
Black shale	—

The flint clay and the overlying soft clay are correlated with the Ellerslie or Lower Kittanning clay. The soft sandy clay has fair plasticity. It burns gray and has the properties of a No. 3 fire clay. It softens at cone 26. It is suited to the manufacture of fire-proofing, hollow and stoneware. The flint clay softens at cone 30. It is somewhat siliceous and is classed as a No. 2 fire clay. With a No. 2 bond clay it should make No. 2 refractories. (Note: The Cooks Mills Company mentioned above is out of business.) The section is believed to have been measured at a prospect in the north bank of Gladdens Run, N.25°W. from the county bridge 100 yards east of the road going up Powder Run, and 50 feet above the run.

Southwest along the strike of the beds on Little Allegheny Mountain and two miles directly west of Ellerslie, Maryland, the Andrew Ramsay Company operated a clay mine until about 1929, since when it has been operated by the Maryland Pottery Co. Mining is carried on in Maryland but the entry is just across the State line in Pennsylvania, near the corner between Bedford and Somerset Counties. Both the Mt. Savage and the Ellerslie clays are present but the Ellerslie clay is the only one worked. This is the equivalent of the Lower Kittanning bed. The clay ranges from 4 to 14 feet thick and is in places all soft gray clay and in other entries is part soft and part brown flint clay. The flint clay softens at cone 33 to 34 and is a No. 1 clay. The plastic clay softens at cone 26 to 30, burns to a gray or buff color and ranges from a No. 3 to a No. 1 clay. The clay was taken to Ellerslie by means of half a mile of steep three-rail gravity plane and 1½ miles of a tram road, but in 1940 it is trucked from the bottom of a 1200-foot plane to the plant. It is used in the manufacture of sanitary ware.

Wellersburg.—North of Wellersburg on the east bank of the north branch of Jennings Run there are poor exposures of the Mt. Savage clay and down stream much better exposures of the Upper Kittanning

horizon carrying the Hardman or Furnace clay bed. The section as given in the Maryland report, page 350, is as follows:

Feet	
	Flaggy sandstone
1.3	Shale
0.8	Coal
1.0	Shale
0.7	Coal, poor (Upper Kitt.)
1.4	Plastic clay with ore balls at base
4.0	Concealed
4.0	Gray shale
12.5	Tough brown flint clay with ore balls
5.3	Soft plastic gray clay with 2 ft. yellow iron-stained top.
2.0	Shale
50.0	Concealed to stream.

The clay immediately below the Upper Kittanning coal softens at cone 22 and is therefore not a fire clay but may have other uses. The flint clay fuses at cone 29 and is a No. 2 fire clay capable of making No. 2 refractories. The plastic clay below the flint clay fuses at cone 24 which is low for refractories. The soft clays might be used as bond clays or in the manufacture of face brick, sewer pipe, etc.

One of the prospects is reported to be in the bank of Jennings Run east of Pleasant Union and one-third of a mile below a rocky ravine.

It is evident then that in the Wellersburg region and in its surrounding mountains there are at least three clays of importance: the upper, the Hardman or Upper Kittanning clay which underlies the horizon occupied farther north by the Johnstown cement limestone; second, the Ellerslie or Lower Kittanning clay; and third, the Mt. Savage clay which is either of the Brookville-Clarion or of the Mercer horizon. At all of the horizons both flint and plastic clay may be expected.

Area Between Allegheny and Negro Mountains

Just west of the crest of Allegheny Mountain is a narrow synclinal area extending from the northeastern corner of the county, through Buckstown, Shanksville, Berlin, Garrett, Meyersdale and Salisbury. It is drained by the Casselman River and its branches in the south and by Stony and Shade Creeks in the north. The eastern part of this area is near the crest of Allegheny Mountain and is underlain by Pottsville sandstones, forming a wild wooded plateau. Near the western edge of the Pottsville rocks or near their junction with the overlying Allegheny group, the Mercer or the Brookville clays are to be expected and these are apt to carry important flint clay beds. The northern township in this area, Ogle, is largely covered by the Pottsville rocks and little is known of its clays. To the south Clear

Shade and Dark Shade Creeks cross the area and in their valleys the Upper and Lower Kittanning coals are mined at Central City and Cairnbrook. Plastic clays should accompany these coals and development should disclose others near the base of the coal measures.

South of the Lincoln Highway (U. S. 30) in Stony Creek Township the wooded surface is made up largely of Pottsville rocks with little clay or shale. Between Buckstown and Shanksville shales of the Conemaugh group make up the surface and some of these might be of value for brick making. A shale sample (no. 340) collected 3 miles east of Shanksville and 0.3 mile west of Boone showed fair green strength and fired to red or brown color with a firing range from cone 3 to cone 9. It fused at cone 16 and seems suitable for brick or tile manufacture.

In the district around Berlin the chief coals mined are the No. 1 or Berlin, now correlated with the Sewickley and the No. 2 or Price coal correlated with the Pittsburgh coal. As usual these higher coals are not accompanied with clays of value. If fire clays are to be found in the Berlin area they will be in the Allegheny group east of the borough on the flanks of Allegheny Mountain.

Garrett.—Between Berlin and Garrett exposures of shales and clays of the Allegheny and the Conemaugh groups are frequent. Two miles north of Garrett along the road just north of a bridge a coal streak in a cliff is underlain by six feet of clay and shale. No. 342 represents a three-foot bed of clay from this locality. It has good plasticity and a high green strength. It fires to a buff with a range from cone 02 to cone 7. It is classed as a No. 2 plastic fire clay and can also be used in the manufacture of buff brick and tile. It fuses at cone 26.

Along the road just north of Garrett a good section of the Allegheny group is exposed, including the Johnstown cement rock and its underlying clay, which corresponds to the Hardman or Furnace clay of Maryland. The section at this locality is as follows:

Feet

10	Brown shale
6	Coal and shale (Upper Kittanning)
6	Dark limestone (Johnstown cement bed)
0½	Iron carbonate
4	Plastic clay with flint clay near base
—	Nodules of iron carbonate
3	Gray clay, some shaly
4	Gray shaly sandstone
3	Black shale, nodular
1½	Sandstone with wavy coaly streaks
—	Carbonate nodules
2	Dark splintery shale
20	Concealed to stream

Sample 343 represents the 4- and 3-foot beds of clay, excluding the thin layer of iron concretions. About one foot of flint clay is included in the sample. The plasticity was fair and green strength fair; it fired to a gray color with a firing range from cone 3 to cone 12 and fused at cone 28. It is thus a fire clay and might be used in the manufacture of various refractories. By careful selection an even better grade of clay might be developed at this point.

Between Garrett and Meyersdale exposures are all in Conemaugh rocks, chiefly shales and thin coals with little clay. A section along the road about midway between the two places is as follows:

Feet	
—	Slabby sandstone
0½	Coal
2	Shale or clay
0½	Coal
2	Clay
3	Limestone
6	Clay or shale
3	Limestone
4	Shale
4	Sandstone
20	Brown crumbly shale
8	Gray shale
0½	Cannel shale
0⅔	Coal
4	Poor stony clay
10	Concealed
30	Buff shale, dark nodular at base (no. 344)
20	Concealed to river

The shale, No. 344, has fairly good plasticity and fair green strength. It fires brown but has a poor firing range and is not considered of much value.

Meyersdale.—Between Meyersdale and Salisbury the Pittsburgh coal and some 200 feet of the overlying Monongahela strata are exposed in the center of the syncline west of the railroad. Shaw¹ made tests on a shale above the Pittsburgh coal one mile north of Boynton (sample 18) and found it to be of little value. He also tested a thin clay above the Pittsburgh coal at Shaw Mines (sample 20) and found it to be a No. 3 fire clay. However, it was but 15 inches thick and therefore of no value. In the Conemaugh group which forms the main outcrops along the railroad south of Meyersdale, little was seen of value. About half a mile north of Boynton along the highway a cliff shows 15 feet of shale underlain in descending order by 9 inches of coal, 2 feet of clay, and 4 feet of limestone.

¹ Shaw, J. B., *Fire Clays of Pennsylvania: Penna. Topog. & Geol. Survey, Bull. M-10, 1928.*

The Otto Brick Works, formerly D. D. Otto & Sons, has been located for 40 years 3 miles west of Salisbury, and three-quarters of a mile north of Springs. Soft fire clay dug at the plant is used for making building brick, hollow tile, silo blocks, sewer tile, and other products. The better clays of this region are no doubt in the Allegheny group, which is confined to narrow belts on the flanks of Negro Mountain and Allegheny Mountain.

Negro Mountain Region

The anticlinal fold known as the Negro Mountain anticline or in Maryland as the Accident anticline, brings to the surface the heavy-bedded Pottsville and Pocono sandstones and forms a rugged mountain ridge which extends from Maryland northeast into Pennsylvania. The anticlinal axis passes midway between Rockwood and Garrett, crosses the Lincoln Highway two miles west of Buckstown, and ends near Old Shade Furnace. South of the Casselman River the mountain maintains a crest altitude of 2,900 to 3,100 or more feet above sea level; north of this river it falls to 2,400 to 2,600 feet and is less prominent. South of the Casselman River the mountain is wild and wooded and its surface is chiefly heavy sandstones. On its flanks clays may occur in the upper part of the Pottsville or the lower Allegheny but none have been uncovered. The best exposures are along the Casselman River which has cut a deep gap through the ridge between Garrett and Rockwood. This course is followed by the Baltimore & Ohio Railroad and by the Western Maryland Railroad. At Garrett the Hardman or Upper Kittanning clay is exposed, as previously described. A few hundred yards west of Garrett the Pottsville sandstones rise westward some 300 feet per mile. The Lower Kittanning (Ellerslie) and the Brookville-Clarion (Mt. Savage) clays should be present. Farther west the red shales of the Mauch Chunk appear, and following them the Pocono sandstones. Passing through the axis of the fold these beds are again encountered and the zone of lower Allegheny and upper Pottsville clays is crossed east of Rockwood. At Rockwood the strata exposed are of middle Allegheny age with the Lower Kittanning horizon 37 feet above the river. In this vicinity the thickest clay seems to underlie the Brookville coal. See beyond for section and test.

Many years ago Harrison Snyder made brick at Rockwood, and prior to 1917 a Mr. Stodler mined clay on the south side of Casselman River one mile east of Rockwood for his brick plant on the north bank of the river.

North of the Casselman River the Allegheny group covers the crest of the mountain and at Wilson Creek mines and Blackfield, the Brookville and Clarion coals are mined. Clays might be developed in this

region along with coal mining. To the north the ridge becomes less prominent although the structure persists. West of Shanksville along Stony Creek some Pottsville rocks are exposed along the axis of the fold. The axis crosses the Lincoln Highway 2 miles west of Buckstown and ends at Shade Creek near Old Shade Furnace. In the vicinity of Old Shade Furnace the valleys of Clear Shade Creek and Dark Shade Creek cut into the Pottsville and Mauch Chunk strata. The higher land in this area carries the Allegheny group and includes mineable coal and probably some clays. Shaw¹ tested a Clarion clay 4½ feet thick on the property of the Arrow Coal Mining Company half a mile north of Cairnbrook. The tests (no. 12) show it to be a semi-flint clay of the quality of a No. 3 fire clay. It extends for half a mile along the railroad between Windber and Central City. The coal mined at Arrow and Ashtola is chiefly the Lower Kittanning but no use is made of the clay underlying it.

Northern Townships

Between Negro Mountain and Laurel Hill is a broad belt of Cone-maugh and Allegheny strata which can be treated as a unit. It includes Windber, Boswell, Jenners, Sipesville, Stoyestown, Somerset, Rockwood, Confluence, and Listonburg.

Windber.—That portion of this western area which lies north of the Lincoln Highway is drained chiefly by Quemahoning, Stony and Shade Creeks. It is an area of intensive mining in the Allegheny coals. In the Windber area the chief coal mined is the Lower Kittanning bed. It is underlain by 3 to 6 feet of clay. Shaw¹ tested a sample (no. 10) from the mine of the Egolf Coal Company, half a mile north of Rummel, the sample being taken from the upper two feet of the clay. It proved to be No. 1 fire clay suitable for the manufacture of refractories. The Brookville coal is not known to have good clay below it. Shaw tested a shaly sample (no. 9) from beneath the Brookville coal in No. 30 mine of the Berwind-White Coal Mining Company, near Scalp Level. This had somewhat the appearance of a flint clay but tests proved that it had poor burning properties and is probably of no value.

The Windber Brick Company, I. Basilio Capannari, manager, operates a well-equipped brick plant just south of Windber on the Pennsylvania Railroad. The section shows as follows:

Feet	
6	Black shale
2	Coal
6	Clay, now mined (no. 362)
6	Shale, used (no. 363)
1	Coal
6	Clay, not now used (Shaw no. 7)

¹ Loc. cit.

These clays are perhaps of the Clarion or the Brookville horizon. The upper clay (no. 362) has good plasticity and fair green strength. It fires to a gray color and has a firing range of cone 02 to cone 7. It fuses at cone 20. The shale (no. 363) is a dark blue, iron-stained shale. It has fairly good plasticity and low green strength. It burns to a tan to dark brown color and has a firing range from cone 3 to cone 12. Face brick varying from buff to light pink in former years were made from various mixtures of this shale and clay. Now the company mines and uses clay for making buff building brick, mine blocks, and backing-up tile. The lower clay, formerly used in the manufacture of paving brick and fire brick, was tested by Shaw as sample No. 7. It proved to be a No. 2 fire clay with a rather low temperature of vitrification. It fused at cone 28½. The brick plant is equipped with roll crushers, two dry pans, a Freese brick machine and Steele cutters. The brick are burned in six round and one rectangular down draft kilns, using coal.

Down Paint Creek valley from Windber exposures of the Pottsville series prevail. One mile down Stony Creek from the mouth of Paint Creek, the Ebensburg anticline brings up the Mauch Chunk red shales and sandstone to a thickness of 140 feet. The Pottsville shows the following section:

- 65 to 90 feet—Homewood sandstone
- 11 “ —Shale, coal, and clay (Mercer)
- 100 “ —Connoquenessing sandstone

South of Kring the Mercer division shows 5½ feet black shale, 3½ feet coal and one foot clay. North of Kring the Allegheny group is well exposed. The upper part of the following section was measured near the Valley Coal and Stone Company property on Stony Creek¹, the middle is typical around Johnstown, and the bottom at Faustwell.

Ft.	in.	
3	3	Upper Freeport coal
14		Shale
10		Dark concretionary shale
25		Blue shale
5		Laminated sandstone
10		Shale and sandy shale
3	1	Lower Freeport coal
2	6	Limestone
8		Shale and sandstone
15		Blue shale
5		Upper Kittanning coal
3	6	Clay
6		Johnstown cement rock
7		Impure clay
8		Shale with iron nodules

¹ Phalen, W. C., U. S. Geol. Survey, Geol. Atlas, Johnstown folio (no. 174), 1910.

Ft.	in.	
19		Dark shale
1	6	Coal
13		Black shale
0	9	Middle Kittanning coal
4		Fire clay
17		Gray sandstone
6		Shale
3	6	Lower Kittanning coal
4	8	Fire clay
50		Kittanning sandstone
2		Shale
3	7	Brookville coal
10		Shale

The Lower Kittanning clay, the clay below the Johnstown cement rock and the clay near the Clarion coal (not shown in this section) offer the best possibilities in this region.

In the uplands west of Stony Creek in northern Conemaugh Township the exposures are chiefly Conemaugh shales. Fifty to 70 feet above the Upper Freeport coal in the Mahoning horizon is a clay which, in the Johnstown region, is sometimes an impure flint. Between Keefer School and Mishler a cliff shows:

Feet	
2	Sandstone and shale
—	Thin coal
10	Brown nodular clay
8	Flint clay (no. 349)

The flint clay (no. 349) probably from the Mahoning horizon, shows poor plasticity. It fires to a light gray and has a firing range from cone 01 to cone 13. It fuses at cone 29 to 30, and seems suited to the manufacture of refractories.

Stony Creek.—North from Kantner, down Stony Creek, through Rowena, Hooversville, Landstreet, Hollsopple, and Foustwell to the mouth of Paint Creek the valley is cut in rocks of the Allegheny group. Conemaugh strata are exposed on the higher divides. Tests were made by Shaw on two clays from this region (see Bull. M-10). The first was on an 8-foot clay below the Upper Freeport coal on the property of the Hillcrest Smokeless Coal Co. two miles north of Kantner. This clay (no. 16) fused at cone 14 and seemed to have such poor burning qualities that it is deemed of no value. The other test was made on a shale under the Lower Freeport coal at the same locality. This shale (no. 17) seems to have very little economic value. At Hooversville the stream flows upon the sandstones of the Pottsville series and the whole of the Allegheny group is exposed. At that point, under the Lower Kittanning coal, about three feet

of plastic clay is to be seen and three feet lower about $4\frac{1}{2}$ feet of poorer clay. These have not been worked or tested.

Jennerstown.—In the region north of Jenners, including the towns of Boswell and Jerome, the higher lands carry the Conemaugh group with its many good shales, and the lower lands the Allegheny group whose coals are extensively mined. Abundant brown shale is present north of Jennerstown and at Jerome and Davidsville. On the east side of the Johnstown road (Route 219), four miles north of Jenners-town and 0.8 mile south of Forwardstown, a shale quarry shows the following section:

Ft.	in.	
3		Shale
1	3	Sandstone
10		Olive shale
1		Sandstone
2		Shale

The shale in this quarry was tested as sample 348. It had good plasticity and high green strength. It fired to a red to dark brown color and had a firing range from cone 01 to cone 9. It is suited to the manufacture of red face brick or tile.

West from Jenners (Ferrell) 0.2 mile along the Lincoln Highway an opening shows the following section:

Feet	
10	Shale
3	Coal
3	Plastic clay (no. 350)
2	Sandstone

This clay has good plasticity and low green strength. It fires to a light gray with a firing range from cone 01 to cone 13. It fuses at cone 29-30 and is suited to the manufacture of refractories. Shaw in Bull. M-10 gives tests on a No. 1 flint clay from below the Upper Freeport coal at this same locality. This possibly underlies the plastic clay noted above.

Several clays near Boswell were tested by Shaw. As reported in Bull. M-10, the following were judged to be of no value: No. 4, a clay between the Upper and Lower Freeport coals; No. 5, a plastic clay in pockets in a heavy sandstone, possibly the Mahoning; and No. 6, a plastic clay below the Middle Kittanning coal. Just west of Boswell, the Upper Kittanning coal has a four-foot bed of semi-flint clay below it (Bull. M 10). A sample (no. 1) came from an abandoned mine of the Davis Coal & Coke Co. It is a No. 1 fire clay fusing at cone $31\frac{1}{2}$ and is suitable for refractories.

Shaw also reports a fire clay (no. 2) under the Lower Freeport coal in the Kelley mine at Boswell. This clay is $3\frac{1}{2}$ feet thick and is classed as a semi-flint clay. It fuses at cone 20 and is suited to the manufacture of face brick or tile.

Western Townships

From the Lincoln Highway to the region around Somerset, the surface is made up chiefly of Conemaugh strata, with Allegheny rocks appearing only in the Stony Creek valley and in the area around Acosta and Ralphtown. In the Conemaugh strata brown shales suitable for brickmaking are common from Jenners to Somerset and all around the Somerset area. In the Allegheny group along the Baltimore & Ohio Railroad between Coleman and Kimmeltown, Shaw (Bull. M 10) notes a No. 1 flint clay (no. 13) under the Upper Kittanning coal. In the same region he notes a 7-foot clay below the Lower Freeport coal in the No. 2 mine of the Olive Coal Company. This clay (no. 14) shows good burning properties and could be used in the manufacture of paving brick, face brick, and tile.

Somerset.—Somerset is located upon shales of the lower part of the Conemaugh group. Common brick were made here prior to 1910 near the railroad at the south end of the borough. It is reported that the flat is underlain by 4 feet of gray clay, below which is 4 feet of yellow clay. A pottery at Somerset formerly made jugs and crocks from local clay.

South from Somerset the main line of transportation is along Coxes Creek to Rockwood. The upper part of the Allegheny group is here exposed and at Bando the Lower Kittanning horizon is about 50 feet above the river. A three-foot clay is present below the Johnstown cement limestone and in some places a clay occurs above the limestone. These clays are similar to those already described near Garrett but appear less pure.

Rockwood.—At Rockwood where Coxes Creek joins the Casselman River, the lower part of the Allegheny group is exposed. Just above the Baltimore & Ohio Railroad, at the station, the following section is to be seen:

Feet	
10	Shaly sandstone
6	Poor clay
6	Sandstone
6	Brownish shale
3	Concealed
4	Dark shale and coal
12	Crumbly clay (no. 341)

This clay is probably the Brookville. It has low green strength and fair plasticity. It fires to a gray color with a firing range from cone 3 to cone 9, fuses at cone 20, and is a low grade fire clay, but should make gray face brick or tile. A similar clay and probably the same, with a thickness of 20 feet occurs at the Shoo Fly tunnel about 9 miles down the river.

Ursina to Listonburg.—Down the Casselman River from Rockwood the coals of the Allegheny group are exposed and no doubt they carry under-clays which might be utilized but exposures are not good and little is known about these clays. Near the junction of the Somerset and Humbert roads just north of Ursina an exposure shows:

Feet	
20	Brown shale and sandstone
3	Coal
3	Clay (no. 346)
3	Coal to road

This clay has fairly good plasticity and fair green strength. It burns to a buff color with a firing range from cone 3 to cone 9. It fuses at cone 28 and might be used in the manufacture of No. 2 fire brick and buff face brick. From Harnedsville to Listonburg the exposed rocks are of the Allegheny group. One mile north of Listonburg along the road the following section is exposed:

Feet	
—	Thin coal
15	Clay and shale
5	Heavy sandstone
0.7	Coal
4	Plastic clay, wet, not sampled.

On the steep hill just north of Listonburg, 20 feet of dark shale is exposed, overlain by 20 feet of sandstone. The shale (no. 347) has fair plasticity and low green strength, burns to a red color, and has a firing range from cone 3 to cone 9. It is suitable for the manufacture of red brick or tile. This is probably a shale near the base of the Allegheny group, possibly above the Lower Kittanning coal. South from Listonburg heavy sandstones predominate and the strata are chiefly of Pottsville age, with a narrow band of Allegheny strata east of Addison. The clays to expect would be those accompanying the Upper Kittanning, Lower Freeport, and Upper Freeport coals. None of these clays have been developed. At the junction of the Listonburg road and the National Pike, brown-stained gray shales occur that would probably make satisfactory red brick.

From Whites Creek west to the Youghiogheny River, which forms the western boundary of the country south of Confluence, the exposed rocks are of the Conemaugh group, with many good shales.

North from Confluence the river turns west toward Laurel Hill, exposing in turn narrow belts of the Allegheny group, the Pottsville sandstones, and the Mauch Chunk red shales and sandstones. No clays are known along this area but there is a possibility of clays in the Allegheny group. North from the Youghiogheny River, the Allegheny group lies on the eastern flank of Laurel Hill in a narrow belt west of Sipesville, Bakersville, and Jennerstown, but clays, if present, are obscured.

Localities where Somerset County clay samples were obtained:

Nos. 1-14 and 16-25 were tested by Shaw and described in Bull. M 10, 1928.

1. Flint clay, Upper Kittanning bed. Davis Coal and Coke Co., west of Boswell.
2. Semi-flint, Lower Freeport bed. Kelley coal mine, Boswell.
3. Flint clay, Upper Freeport bed. Geo. Wichpenheiser land, Jenners.
4. Semi-flint clay, Bolivar bed. E. Gonder farm, 2 miles from Jenners Cross Roads.
5. Plastic clay, in Pottsville beds. R. D. Phillipi, southeast of Boswell.
6. Plastic clay, Middle Kittanning bed. Along Jenners-Boswell road.
7. Semi-flint clay, Clarion bed. Windber Brick Works, southeast of Windber.
8. Semi-flint clay, under Johnstown cement rock. Valley Smokeless Coal Co., west of Kring.
9. Shale, under Brookville coal. Berwind-White Co. No. 30 mine, Scalp Level.
10. Flint clay, Lower Kittanning bed. Egolf Coal Co., $\frac{1}{2}$ mile north of Rummel.
11. Shale and clay, Lower Kittanning bed. Loyal Hanna Coal and Coke Co. mine, Cairnbrook.
12. Semi-flint clay, Clarion bed. Arrow Coal Mining Co., $\frac{1}{2}$ mile northeast of Cairnbrook.
13. Flint clay, Upper Kittanning bed. Along B. & O. R. R., between Coleman and Kimmelfton.
14. Plastic clay, Lower Freeport bed. Olive Coal Co. No. 2 mine, between Coleman and Kimmelfton.
16. Plastic clay, Upper Freeport bed. Hillcrest Smokeless Coal Co., 2 miles northeast of Stoyestown.
17. Shale, under Lower Freeport coal. Jos. Birkeypile land, 2 miles northeast of Stoyestown.
18. Shale, over Pittsburgh coal. C. K. Bowman mine, 1 mile north of Boynton.
19. Plastic clay, Mercer bed. Owned by R. H. Whitford, Meyersdale.
20. Plastic clay, above Pittsburgh coal. Consolidation Coal Co., Shaw Mines.
21. Flint clay, Mercer bed. Keystone Fire Brick Co. mine, 2 miles east of Meyersdale.
22. Flint clay, Mercer bed. Savage Brick Co., Williams.
23. Plastic clay, Sharon bed. Savage Brick Co., Williams.
24. Plastic clay, Sharon bed. L. M. Neld land, Fairhope.
25. Plastic clay, Mercer bed. L. M. Neld land, Fairhope.

340. Shale, along road 0.3 mile west of Boone.
 341. Plastic clay on railroad at Rockwood.
 342. Plastic clay on road 2 miles north of Garrett.
 343. Flint and soft clay under Johnstown limestone, $\frac{1}{2}$ mile north of Garrett.
 344. Shale, 2.1 miles south of Garrett on Meyersdale road.
 346. Clay, $\frac{1}{2}$ mile north of Ursina on Somerset road.
 347. Shale on hill north of Listonburg.
 348. Shale, 4 miles north of Jennerstown on road to Johnstown.
 349. Flint clay, shaly, between Keefer School and Mishler, along the road.
 350. Plastic clay, 0.2 mile west of Jenners (Ferrell), on Lincoln Highway.
 362. Upper clay, Windber Brick Co., Windber.
 363. Shale, Windber Brick Co., Windber.

Physical tests of Somerset County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking in minutes	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage at cone	Fusion point, cone	Best burning range, cones	Firing color	Suggested uses
1	22.67	12.63*	4		10.37*	11	31½			No. 1 fire clay
2	18.36	15.76*	13		16.93*	9	20			Face brick, tile
3	23.01	10.04*	11		23.74*	14	32			No. 1 flint clay
4	25.22	20.11*	11		21.5*	6	20			Brick, tile
5	25.54	15.64*	19		30.3*	9	26½			Doubtful value
6	24.11	10.83*	22		25.22*	9	26			Doubtful value
7	31.87	21.51*	4		25.60*	9	28½			No. 2 fire clay
8	24.13	9.96*	6		30.10*	9	20			Doubtful value
9	21.13	13.05*	7		22.09*	9	16			Doubtful value
10	21.48	9.80*	3.5		27.10*	14	32			No. 1 flint clay
11	21.52	7.91*	3		32.57*	14	15½			Doubtful value
12	24.25	10.7*	5		28.88*	9	26			No. 3 fire clay
13	22.04	9.99*	2		6.92*	14	32			No. 1 flint clay
14	23.69	15.99*	16		25.05*	9	19			Paving or building brick
16	24.13	17.16*	9		19.36*	6	14			No value
17	21.37	16.14*	4		20.38*	6	16			Doubtful value
18	24.84	14.63*	5		27.10*	6	18			Doubtful value
19	26.06	16.50*	5		34.57*	9	17			Doubtful value
20	21.64	20.92*	5		22.86*	9	20½			Paving or face brick
21	24.10	13.95*	2.5		20.78*	6	34			No. 1 flint clay
22	20.11	2.23*	1.5		15.32*	9	30			No. 1 flint clay
23	20.77	9.98*	5.5		18.13*	9	26½			No. 3 fire clay
24	19.13	10.97*	5.5		21.38*	9	18			Doubtful value
25	20.06	17.56*	5.5		20.78*	9	26½			No. 3 fire clay
340	25.8	4.7	7	207	8.8	6	16	1-6	Red to brown	Brick, tile
341	20.0	2.4	5	178	7.3	9	20	1-6	Gray	Brick, tile
342	22.9	8.0	6	396	6.4	4	26	02-4	Buff	Brick, No. 2 fire brick
343	20.1	3.0	6	252	6.1	11	28	1-9	Gray	Refractories
344	24.2	4.7	3	255	8.5	1	15		Brown	Little value
346	18.2	3.6	4	230	5.4	4	28	1-6	Buff to gray	Face brick, No. 2 fire brick
347	19.4	3.1	7	135	7.4	6	15	1-6	Red to brown	Brick, tile
348	23.1	4.9	6	408	7.4	4	18	02-6	Red to dark brown	Face brick, tile
349	17.5	2.0	3		1.8	11	30	02-11	Light gray	Refractories
350	19.0	5.1	6	171	5.8	11	30	02-11	Light gray	Refractories
362	19.5	3.8	4	220	6.2	4	20	02-4	Gray	Face brick
363	20.6	3.0	3	144	7.6	6	17	1-9	Tan to dark brown	Face brick, tile
P20	23.0	6.3	3				22			
F8					1.7*	1	29		Buff	No. 2 refractories
P21	21.0	5.3	3.5				24			
P25	18.7	5.1	5.4		9.9*	6	26		Gray	No. 3 fire clay
F9					1.8*	1	30		Buff	No. 2 refractories

* Volume shrinkage.

The following tests were made by the Maryland Geological Survey and published in vol. 11 of the Md. Geol. Survey, 1922.

P 20. Clay from north branch of Jennings Run, 3 miles north of Wellersburg, p. 469.

F 8. Flint clay, same locality as P 20, p. 470-471.

P 21. Plastic clay, same locality, p. 470-471.

P 25. Plastic clay, clay prospect. Cooks Mills Coal and Lumber Co., Cooks Mills, p. 471.

F 9. Flint clay, same locality as P 25.

Chemical analyses of Somerset County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
1	10.10	55.58	3.97	.01	28.62	.81	.63	.08	.21	.02	.00	.04
2	7.33	61.92	3.51	.28	23.56	.50	.89	.87	1.11	.07	.008	.08
3	12.43	46.25	3.38	.26	37.50	.16	.27	.54	.28	—	—	—
4	7.65	48.28	2.96	.61	29.91	2.56	1.01	3.72	3.06	—	—	—
5	5.10	62.80	2.23	.47	26.31	.97	.04	2.81	.34	—	—	—
6	5.65	65.69	3.91	.37	18.65	1.27	1.35	.59	2.08	—	.03	—
7	6.48	60.65	4.60	.18	23.80	.30	.90	.56	1.12	—	.03	1.64
8	5.42	59.23	3.52	.87	26.46	1.32	1.23	.46	.86	.03	.02	.18
9	4.91	70.68	6.97	.62	13.18	1.17	.98	.78	.42	.06	.18	.22
10	12.58	47.66	4.12	.19	32.90	.64	.95	.96	.50	—	—	—
11	9.50	58.33	7.52	1.28	17.44	2.07	1.70	.24	.36	.05	.02	1.61
12	7.63	61.99	4.24	.79	23.08	.66	.15	.47	.56	.16	.08	.24
13	8.58	62.75	1.85	.86	23.02	1.50	.74	.21	.33	.02	.06	.63
14	—	58.26	3.71	1.50	28.81	.47	.38	—	—	—	—	—
16	8.43	55.51	6.11	.64	21.14	3.19	1.10	.54	1.06	.09	.04	2.39
17	12.32	51.53	3.67	.17	28.22	.92	.81	1.08	.85	.17	.15	.06
18	8.20	55.67	3.00	.79	25.70	1.01	1.06	.58	1.07	.00	.04	.78
20	10.83	58.83	3.27	.22	22.78	.66	.68	1.49	1.09	.04	.01	.10
21	3.81	46.57	3.78	.17	36.52	1.27	1.41	2.01	4.40	.05	.03	.08
22	12.40	51.74	3.47	.17	28.33	.91	.86	1.02	.85	.00	.13	.04
23	6.87	59.54	2.62	.76	27.52	.70	1.17	1.04	.62	—	—	—
24	7.79	57.95	4.02	.33	25.68	1.21	1.38	.96	.78	—	—	—
25	6.93	58.53	3.68	1.47	28.73	.44	.36	—	—	—	.08	—
340	7.13	56.15	8.30	1.20	21.55	1.40	1.84	.70	.83	.21	.15	.14
342	6.89	56.12	9.02	.87	24.10	.73	1.28	2.26	1.97	.41	Tr.	.16
343	7.75	60.83	3.61	.15	26.83	.53	.32	—	—	.92	.02	—
344	9.25	51.82	11.67	.56	19.99	.72	2.43	.72	1.31	.17	.07	2.00
346	6.58	62.50	3.43	.11	22.75	1.10	1.04	1.61	.29	.04	.09	.17
347	8.17	57.26	6.63	.76	22.66	.85	1.86	—	—	.05	.12	.61
348	6.04	60.84	7.85	.81	21.42	.94	1.93	.14	.09	.04	.13	.15
349	8.23	61.52	7.10	.22	20.71	.77	.28	—	—	.35	.08	—
350	6.35	67.62	3.26	.27	19.85	.88	.62	.28	.18	.27	.03	.53
362	7.65	61.79	3.12	1.50	22.65	.53	1.84	3.30	—	.02	.17	.17
363	7.98	57.73	8.05	.83	20.82	.95	.14	—	—	.40	—	—
F8	7.21	68.26	2.31	.90	19.30	.00	.08	.50	1.00	—	—	S.11
P25	4.37	73.22	1.60	1.51	16.10	.00	.12	2.24	.17	—	—	S.05
F9	7.15	69.26	1.06	2.01	19.00	.00	.12	.50	.21	—	—	S.08

Selected references to the geology of Somerset County:

Hall, G. M., Description of fire clay localities: Maryland Geol. Survey, vol. 11, pp. 347-375, 1922. Has notes on several Somerset localities.

Lesley, J. P. (and Harden, E. C.), The coal beds and fire clays of the Wellersburg basin in Somerset County: Second Penna. Geol. Survey, Ann. Rept. for 1885, pp. 227-249, 1886.

Martin, G. C., U. S. Geol. Survey Geol. Atlas, Accident-Grantsville folio (no 160), 1908. Describes the geology of the southern edge of Somerset County.

Phalen, W. C., U. S. Geol. Survey Geol. Atlas, Johnstown folio (no. 174), 1910.

Platt, F., and W. G., Report of progress in the Cambria and Somerset districts of the Bituminous Coal Fields of western Pennsylvania, pt. 2, Somerset County: Pennsylvania Second Geol. Survey, vol. H 3, 1877.

Atlas to accompany reports H 2 and H 3: Pennsylvania Second Geol. Survey, 1889; gives a revision of the Wellersburg section.

Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Somerset-Windber folio (no. 224), 1934.

Schurecht, H. G., The testing of the clays: Maryland Geol. Survey, vol. 11, pp. 409-539, 1922. Includes some tests on Somerset County clays.

Shaw, J. B., Fire clays of Pennsylvania (partial report): Pennsylvania Topog. & Geol. Survey, Bull. M 10, 1928.

Sisler, J. D., Bituminous coal fields of Pennsylvania: Pennsylvania Topog. & Geol. Survey, vol. M 6, pt. 2, 1926. The coals of Somerset County are described on pp. 345-394.

SULLIVAN COUNTY

Sullivan County lies south of Bradford County in the high plateau area of the northeastern part of the State. It is primarily a plateau of Pocono sandstone slightly folded into two synclinal troughs with two lower anticlinal areas of Catskill red beds. Within the main synclinal area which crosses the county from east to west through Lopez, Ringdale, Laporte, and Eagles Mere is the small Bernice coal basin of Pottsville sandstones overlain by coal-bearing shales. The anthracite beds are accompanied by slaty shales of little value. The Pocono plateaus furnish no clays or shales. The lowlands carved from Catskill shales along anticlinal axes lie along Muncy Creek through Muncy Valley and Nordmont, and in the northern part of the county from Colley and Dushore west to Forksville, Eldredville, Lincoln Falls, and Shunk. It is in these lowlands that we may expect brick shales since some soft red shales, when weathered, make excellent material for red brick manufacture.

Good red shales occur near Dushore and northeast along Route 87 for miles. They might be developed along the Lehigh Valley Railroad near Dushore or along the Muncy Valley.

Sullivan County lies within the glaciated area and many of the low valleys have deposits of glacial clays which might be developed by small brick or tile plants. At present there are no clay industries in the county.

Reference to the geology of Sullivan County:

Sherwood, A. (and Platt, D.), The geology of Lycoming and Sullivan Counties: Pennsylvania Second Geol. Survey, vol. GG, 1880.

SUSQUEHANNA COUNTY

Susquehanna County is in the northern tier and just west of Wayne County in the northeast corner of the State. It is, in general, a high glaciated plateau drained by small streams radiating from its center and flowing north, west, and south into the North Branch of the Susquehanna River which comes into the county in a deep valley in the northern townships through Lanesboro, Oakland, and Great Bend. Tunkhannock Creek carries waters to the south and Wyalusing Creek to the west.

The county is traversed by branches of the Delaware, Lackawanna and Western Railroad, north and south through the center of the county, and by the Delaware and Hudson Railroad along its eastern border. It is also well served by many good highways.

The county is underlain by nearly horizontal strata of Upper Devonian, Mississippian, and Pennsylvanian age, the rocks of the latter two periods appearing only in a very small area in the southeastern corner. A general section of the exposed strata is as follows:

		Feet	
Pennsylvanian	Coal Measures	400	
Mississippian	{ Mauch Chunk shale	150	
	{ Pocono sandstone	300	
Devonian	{ Catskill	{ Mount Pleasant shale	475
		{ Elk Mountain sandstone	170
		{ Cherry Ridge sandstone	400
		{ Honesdale sandstone	100
		{ Damascus shale	125
	{ New Milford	{ Lanesboro flags	350
		{ Kingsley shales	100
	{ Chemung (Cayuta) shales	100	

The Pennsylvanian and Mississippian strata crop out only near Forest City at the northern end of the great Lackawanna syncline. High knobs and ridges of Pocono sandstone enclose red and gray Mauch Chunk shales and some slaty shales and anthracite beds of the Pennsylvanian period. Mauch Chunk shale would be the only brick shale of the area and no good exposures of this are known. The Catskill beds or continental phase of the Upper Devonian crop out in the southeastern townships east of a line from Thompson southwest to Nicholson in Wyoming County. They are exposed along the Delaware and Hudson Railroad, south from Thompson and along the highways through Clifford, Lenox, Dundaff, and Gelatt. The red Mount Pleasant shale has been made into brick at the State Hospital in Wayne County and tests were made of it (no. 334) in Wayne County as exposed near Waymart on Route 6. The softer and well-weathered material should be available for brick and tile manufacture.

The soft, red Damascus shale has been used for brick at White Mills, Wayne County. It crops out in a belt southwest from Thompson. A small area of Damascus shale also surrounds Montrose.

The New Milford formation was originally mapped as a part of the Catskill formation, but is now known to be in part marine. Its upper 100 feet is classed as the Canadaway and the rest as the Wellsburg of the Chemung. It underlies most of the central part of the county. It is chiefly made up of thin-bedded grayish sandstones or flagstones but has near its base about 100 feet of red (Kingsley) shales such as are exposed on the Delaware, Lackawanna and Western Railroad at Kingsley. This part of the New Milford formation might be used in brick making if well weathered.

The Chemung (Cayuta) formation, definitely marine, crops out along the Susquehanna River and its tributaries in the northern tier of townships and in the lower valleys on the west and southwest borders of the county. It is primarily a series of alternating thin sandstones and olive-green shales. Some of the latter might be of sufficient thickness for brick making but this is doubtful.

The entire county is within the glaciated belt and unstratified boulder clays and stratified or varved clays of ponded or glacial lake origin are common, especially in the deeper valley, such as the Susquehanna. By removing the rocks the boulder clays may be utilized in brick making. The stratified clays formed in glacial lakes are free from boulders and may be used without further preparation. Glacial clays are usually very plastic and red-burning. They make satisfactory common brick, drain tile, flower pots, and some types of stoneware and art ware. Mr. D. S. Harding in the Susquehanna Evening Transcript of December 18, 1939, describes the glacial clays of the Susquehanna River area in Susquehanna County and gives the history of their former use. He describes five deposits as follows:

1. Between Stevens Point and Brandt in Starrucca Valley. Formerly used in making brick, architectural tile, and flower pots.
2. Near the railroad junction at J. N. tower. Clay is banked along the north side of the Starrucca Valley to a height of 140 feet above the stream. A brickyard operated here for 30 or 40 years.
3. Varved clay deposit at West Oakland. Never used.
4. On Stevens farm, $2\frac{1}{2}$ miles west of Susquehanna on the south side of the Susquehanna River. Formerly used in brick making.
5. A large deposit $\frac{3}{4}$ mile down the river from the Stevens deposit. Never used.

These and many other similar glacial clays could be utilized in small brick or tile plants or in the development of small potteries. At present there are no brick yards in the county.

Selected references to the geology of Susquehanna County:

Harding, D. S., A description of the glacial clays: Susquehanna Evening Transcript, Dec. 18, 1939.

White, I. C., The geology of Susquehanna and Wayne Counties: Pennsylvania Second Geol. Survey, vol. G 5, 1881.

Williard, B., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

TIOGA COUNTY

Tioga County lies along the northern border of the State, just east of Potter County, in the region of plateau uplands or the Allegheny Plateau area. All parts, except the southwestern corner, are within the area of glaciation.

The strata have been gently folded and the erosion of these folds has resulted in alternating mountainous belts in the synclinal areas and lower lands in the areas under the anticlines. The trend of the folding and thus the surface structure is in a direction slightly north of east. The higher synclinal mountains rise to heights of 2,000 to 2,300 feet above sea level; the anticlinal areas range 200 to 400 feet lower. The strata exposed throughout the county show a general average section as follows:

	Feet
Allegheny group	180
Pottsville series	150
Mauch Chunk red beds	25
Pocono series	800
Oswayo formation	160
Cattaraugus formation	900
Chemung group	1,500

Chemung group. The thickness of the Chemung ranges from 800 to 2,000 feet. It consists chiefly of greenish to gray, slabby sandstones interbedded with olive shales. Marine fossils are frequent and there are occasionally thin limy beds crowded with brachiopods. The shales are seldom exposed in outcrop because of the dominance of the more sandy beds. Probably shale beds are present of sufficient purity for the making of red brick and tile but the predominant strata are too sandy. The belts of Chemung strata cross the county along the axes of the four prominent anticlinal folds. These are the Harrison anticline, cutting the northwest corner of the county; the Sabinsville anticline, extending from the northeast corner of the county southwestward, crossing the Tioga River between Lawrenceville and Tioga; the Wellsboro anticline south of Tioga and Pine Mountains, and including Mansfield and Wellsboro; the Towanda anticline along the southeastern edge of the county. Chemung strata are prominent in areas such as Wellsboro, Mansfield, and Tioga to Lawrenceville.

Cattaraugus formation. Although there is some doubt as to the exact correlation and subdivision of the Upper Devonian, the junction coming approximately at the change in color from the grays of the Chemung to the reds of the overlying Cattaraugus beds is marked. The Cattaraugus beds include about 900 feet of strata which are dominantly red shales and reddish sandstones, generally known as the "Catskill red beds." Belts of this material border the belts of Chemung previously described, lying on the flanks of the more moun-

tainous Oswayo areas. The red Cattaraugus shales are often free enough from sandstone layers so that brick shales could be excavated. Experience in other counties shows that they can be made into brick and tile.

Oswayo formation. The Oswayo is described by Willard as a sandy shale formation about 160 feet thick in Tioga County and of Catskill age.

Pocono formation. Several hundred feet of strata prevailingly greenish gray thin-bedded and cross-bedded sandstones are probably roughly the equivalent of the Pocono or Lower Mississippian. They form the resistant rock of the synclinal mountain belts, as along the Pine Creek syncline in Tioga and Pine Mountains and along the Blossburg syncline in Bloss Mountain. They have little shale and seem of little value in brick making.

Mauch Chunk series. The Mauch Chunk has been identified in only a few localities along the Pine Creek syncline and is more prominent in the Blossburg syncline. It is usually less than 50 feet thick and is made up of red shale with sandstone layers. Its thinness and its usual isolation on higher knobs precludes its use in brick-making.

Pottsville series. The Pottsville is made up of a lower massive sandstone or conglomerate of 60 to 100 feet (the Olean), a middle member of coals, clays and shales (the Mercer), and an upper member of thin-bedded sandstones 30 feet thick. The Pottsville appears on the higher knobs in the center of the synclinal mountains. Along the Pine Creek syncline it occupies small areas near the head of Painters Run and on west to areas north of Gaines. One area near Gurnee carries several thin coals which have been mined. The section shows:

	Feet
Buff laminated sandstone	25
Black shale	5
Coal (1½ to 4 feet thick)	3
Fire clay	2
Gray sandstone	10
Black shale	15
Fire clay	5
Buff sandstone, in part shaly	30
Black shale	15
Fire clay with coal streaks	5
Sandstone	60
Black shale with 3 in. coal	5
Greenish shaly sandstone	15

These are thought to be Mercer coals. The fire clays noted have not been studied, but they might yield some refractory clays of value. Larger areas of the Pottsville series lie in the Bloss Mountain area under the coal fields of Blossburg, Arnot, and Antrim. Whether these also carry coals and clays of Mercer age is not known.

Allegheny group. The Blossburg syncline is deep enough to bring in large areas of Allegheny strata along its axis. These areas constitute the coal basins in the vicinity of Blossburg, Arnot, and Antrim, from which semi-bituminous coal has been mined for many years. The coal beds seem to represent the entire Allegheny group but their correlation is not established with certainty. Their position and names are as follows:

	Feet
Seymour coal	2 to 5
Interval	100
Morgan coal	1 to 3
Interval	40
Bloss coal	2 to 5
Interval	20 to 40
Bear Creek coal	1 to 2

The Bloss has been tentatively correlated with the Lower Kittanning. It is now the best coal of the four but with its exhaustion the Bear Creek or the Seymour may be mined. The condition of the underclays as refractories has not been studied but it seems probable that the Blossburg area is the most promising in the county for the development of plastic fire clays and brick shales.

Glacial clays. The Pleistocene ice sheets covered all of the county but its southwest corner. Clays left by these glaciers are to be seen along many of the streams, including boulder clays and clays deposited in glacial lakes. Shales are generally preferred to glacial clays in brick making but a good deposit of plastic glacial clay can be made into common brick, drain tile and sometimes into face brick. One brick yard in operation in the county 40 years ago utilized this clay. This was the yard of J. M. Seaman, west of the Westfield fairgrounds. His pit showed 4 to 18 feet of red laminated clay resting on 4 to 5 inches of gravel, underlain by bluish clay.

No tests were made of any of the shales or clays and no clay products are now made in the county. It would appear, however, that refractory clays might be obtained with the coals of Blossburg or Gurnee; that brick shales might be used in the Cattaraugus series; and that brick or tile could be made from the glacial clays.

Selected references to the geology of Tioga County:

- Fuller, M. L., and Alden, W. C., U. S. Geol. Survey Geol. Atlas, Gaines folio (no. 92), 1903.
- Fuller, M. L., Alden, W. C., U. S. Geological Survey Geol. Atlas, Elkland-Tioga folio (no. 93), 1903.
- Sherwood, A., and Platt, F., The Geology of Bradford and Tioga counties: Pennsylvania Second Geol. Survey, Report G, 1878.
- Sisler, J. D., Bituminous Coal Fields of Pennsylvania: Penna. Topog. & Geol. Survey, Bull. M 6, pt. 2, 1926.

UNION COUNTY

Union County lies east of Centre and Clinton Counties and is bounded on the east by the Susquehanna River. It is in the midst of the folded Appalachian Mountains, the Ridge and Valley section. The trend of the folding is north of east. The strata of the county range in age from the Upper Ordovician through the Silurian and the Devonian, the youngest sediments being the Catskill division of the Upper Devonian seen only in the extreme southeast corner of the county at the Susquehanna River. The north, west, and south borders of the county are largely made up of highlands of the Tuscarora formation, the lower Silurian sandstone and quartzite. The central and larger part of the county is underlain by Silurian shales, chiefly the Clinton shales. Along the Susquehanna River three small areas of the Helderberg limestone, Oriskany sandstone, and the Middle Devonian shales and sandstone occur. These are, (1) a narrow belt in the extreme north end of the county, (2) a small synclinal area near Lewisburg, and (3) a narrow belt south from Winfield, where the Catskill red beds also appear.

The Clinton or other Middle Silurian shales offer the best chance of development as brick shales. They include soft, colored shales that underlie a large area in much of the lowlands and along the railroad along the Susquehanna River. They are not used in the county but their value is demonstrated in the two large brick plants at Watson-town, across the river in Northumberland County. They could be developed along the river from Winfield to Lewisburg and through New Columbia, White Deer, and Allenwood. They also could be developed on the railroad from Lewisburg west to Weikert.

The shales of the Middle Devonian are usually suitable for brick manufacture, especially the Mahantango (Hamilton) shale. These shales appear along the river opposite Northumberland and a sample of the shale two miles north of that city was tested (see Northumberland County) and proved to be a good brick shale. A second area where shales of this character could be dug is just north of Lewisburg, and a third area is at the north county line along the river.

The softer red shales of the Catskill formation usually make good brick and such shales are available opposite Sunbury and Northumberland along the Reading Railroad. Reddish glacial clays extend up the West Branch of the Susquehanna as far as Winfield but they are seemingly of little value as brick clays. No brick or tile are made in the county.

Selected references to the geology of Union County:

d'Inwilliers, E. V., Report on the geology of the four counties, Union, Snyder, Mifflin, and Juniata: Pennsylvania Second Geol. Survey, vol. F 3, 1891.

Willard, B. (et al.), The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

VENANGO COUNTY

Venango County lies in the high portion of the Allegheny Plateau, east of Mercer County. It is deeply dissected by the Allegheny River and French Creek, along which streams are the chief industrial areas such as Franklin and Oil City.

The strata exposed range from Mississippian sandstones and shales, through the Pottsville series and into the lower part of the Allegheny group. Along the main valleys the Mississippian beds are exposed. On a few knobs and highlands in the southern and southeastern borders are to be seen some of the lower coals and other strata of the Allegheny group. The remainder and the larger part of the county is underlain by the Pottsville series, chiefly sandstone beds.

The Mississippian shales and associated thin sandstone beds are exposed along the river roads near Franklin, and up the Allegheny River to Oil City, and beyond. By careful selection it would be possible to use the purer bluish shales in brick manufacture. Three samples were taken with the following results:

Sample No. 383 is of a six foot bed of blue shale, half a mile south of Franklin on the river road. This has good plasticity and low green strength. It burns to a salmon to dark red brown with a burning range of 1,100 to 1,200° C.

Sample No. 384 is from a similar shale one mile east of Reno on the Franklin-Oil City road. This has properties similar to No. 383 but has a slightly higher range, 1,150 to 1,250° C.

Sample 385 represents a shale along the Oil City-Titusville road about half a mile south of Kaneville. Its properties were similar to those of sample 384. All three are suitable for the manufacture of red brick and tile and all are very accessible.

The Pottsville series occurs throughout most of the county. Its thickness is about 130 feet and it is made up chiefly of thin to thick-bedded sandstones. Although shales representing the Mercer horizon should be in the middle of this series, none were noted nor were any flint fire clay deposits seen such as occur farther south.

The lower part of the Allegheny group in the higher knobs in the inter-stream areas shows outcrops of the beds from the Kittanning sandstone down to the Brookville coal. Shales suitable for brick-making should be present in this group. More important, however, is the possibility of plastic or flint fire clays beneath the Clarion or the Brookville coals. These have been used in other counties and should be present in the small areas of the Allegheny group.

The only clay noted was one beneath a thin coal bed along the road two miles west of Clintonville. Here is exposed about 5 feet of clay, the lower three feet sandy. The upper two feet were sampled as number 389. This clay showed very good plasticity and fair

green strength. It fires to a cream to light gray, with a burning range of 1,100 to 1,300° C. It fuses at cone 29. Evidently it is a plastic fire clay of medium quality and suited to the making of refractories. It may be taken as an example of the possibility of fire clays in the Allegheny group.

The northwestern tier of townships lies within the glaciated belt and there is a possibility of the use of the bluish glacial clays in the manufacture of red brick and drain tile. No good banks of this clay were noted.

Physical tests of Venango County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (in minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point at cone	Best burning range (cones)	Firing color	Suggested uses
383	21.	4.2	3	114	6.2	4	15	02-4	Salmon to dark brown	Red brick
384	22.9	3.4	6	198	7.8	4	13	1-6	Salmon to dark brown	Red brick
385	22.2	3.1	4	153	7.7	4	15	1-6	Salmon to dark brown	Red brick
389	24.7	5.9	8	211	7.2	11	29	02-9	Cream to gray	Refractories

Chemical analyses of Venango County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₂
383	4.67	61.62	4.28	1.06	18.70	.31	1.02	.21	.11	.02	.06	—
385	4.37	65.94	12.81	.63	10.28	.00	1.33	3.48	—	.05	—	—
389	7.78	56.76	8.87	1.03	21.91	1.04	.17	—	—	.60	—	—

383 Blue shale, Franklin.

384. Blue shale, 1 mile east of Reno.

385. Shale, Kaneville.

389. Underclay, Clintonville.

Selected references to the geology of Venango County:

Carll, John F., Report of progress in the Venango County district: Pennsylvania Second Geol. Survey, Report I, 1875.

Shaw, E. W. (with E. F. Lines and M. J. Munn): U. S. Geol. Survey Geol. Atlas, Foxburg-Clarion folio (no. 178), 1911.

Shaw, E. W. (with E. F. Lines and M. J. Munn): Coal, Oil and Gas of the Foxburg district: U. S. Geol. Survey, Bull. 454, 1911.

WARREN COUNTY

Warren County lies east of Erie and Crawford counties along the northern border of the State. It is a part of the high northern plateau area and is deeply dissected by the valleys of the Allegheny River, Conewango Creek, Brokenstraw Creek and others.

The exposed strata range from the Pottsville series of the Pennsylvanian period, through the Mississippian strata and down to the Upper Devonian beds. These strata consist chiefly of sandstones, conglomerates and sandy shales with only limited amounts of true clay shale.

The Pottsville strata lie chiefly in the higher hills of the southern part of the county. The series is made up of coarse conglomerates and sandstones with a few thin coal beds and accompanying dark shales. No good fire clays are known with the coals, but the dark shales might be used in brick making. Forty feet of such shales are exposed seven miles southwest of Warren, south of Liberty School (Folio 172).

Below the Pottsville series lie the Mississippian strata with an average thickness of 400 feet. The upper part is the Cuyahoga formation which carries some bluish shales interbedded with more sandy beds and thin conglomerates. The lower part is much more sandy and includes the Berca and the Knapp sandstones. The Mississippian beds form the greater portion of the uplands of the county. They contain bluish shales which might be used in brick-making but these are generally less accessible than the lower shales along the main river valleys.

Below the Knapp formation, of the Mississippian, lie 300 feet of Upper Devonian strata known as the Conewango beds. These consist of green, gray and red shales with thin sandstones and with conglomerate lentils, of which the Salamanca conglomerate is the most important. The Conewango shales appear along most of the valleys and are seen west of Warren on the Allegheny River and Brokenstraw Creek; north of Warren along Conewango Creek and east of Warren along the Allegheny River as far as Kinzua. Shale near the base of the Conewango, the Tanners Hill red shale, is accessible in Warren and might be used in making red brick. At Youngsville, the Keystone Face Brick Company use a gray-purple shale in making red brick. It is probably Conewango material. A sample of this shale (422) has a plasticity rating of 80 and a linear drying shrinkage of 5 percent. It reaches a maximum burning shrinkage of 25 percent by volume and fires red. It fused at cone 15. A shale along the railroad in the west end of Warren, sample 425, has a plasticity rating of 80 and a linear drying shrinkage of 5 percent.

It reaches a maximum burning shrinkage, by volume, 21.6 percent. at cone 9 and has a burning range from cone 1 to 9. It fuses at cone 17. It is an excellent shale for face brick and tile manufacture.

Much bluish shale of the Conewango formation is seen in the cliffs along the Allegheny River south from Irvine to Tidioute. Sample 386 was taken along Route 62 four miles south of its junction with Route 6. It shows good plasticity, low green strength, burns to a salmon to dark brown with a firing range of 1,100° to 1,200° C, and seems suitable for red brick manufacture. Sample 387 was a similar shale 3.8 miles farther south and 8 miles north of Tidioute. This shows fair plasticity, fair green strength, burns salmon to dark brown, and has a firing range of 1,150° to 1,250° C. It also is suited to red brick manufacture. These shales are accessible on both sides of the river and could easily be utilized. They are of the Cattaraugus or Salamanca group.

Physical tests of Warren County clays

Sample number	Percent water of plasticity	Percent linear drying shrinkage	Time of slaking (in minutes)	Modulus of rupture pounds per sq. in.	Maximum linear burning shrinkage	Maximum shrinkage (at cone)	Fusion point at cone	Best burning range (cones)	Firing color	Suggested uses
386	24.	2.6	8	194	8.4	4	15	02-4	Salmon to dark brown	Red brick
387	28.5	5.4	4	225	8.1	1	15	1-6	Salmon to dark brown	Red brick
422		5.0			25.0*	7	15	1-7	Red	Face brick, hollow tile
425		5.0			21.6*	9	17	1-9	Red to brown	Face brick, tile

* Volume.

Chemical analyses of Warren County clays

No.	Ign	SiO ₂	Fe ₂ O ₃	TiO ₂	Al ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	SO ₃
386	4.64	61.45	7.23	.22	21.00	.55	2.36	—	—	.07	.13	.13
387	6.04	60.96	7.83	—	—	1.03	1.87	.51	.31	.09	.13	.12

386. Shale, on Allegheny River, 4 miles south of Irvine.

387. Shale, on Allegheny River, 8 miles south of Irvine.

422. Shale, Keystone Face Brick Co., Youngsville.

425. Shale, west end of Warren.

Selected references to the geology of Warren County:

Butts, C., U. S. Geol. Survey Geol. Atlas, Warren folio (no. 172), 1910.

Carll, J. F., The geology of Warren County: Pennsylvania Second Geological Survey, vol. 14, pp. 149-406, 1883.

Below the Conewango shales there are thick series of shales and sandstones classed as Chemung. These are exposed only in the deeper northern valleys as along the Allegheny River north from Kinzua and along the upper Conewango Creek. No tests were made on them but red, purple, and gray brick shales are included in the formation.

The northwestern half of the county lies within the glaciated belt and the uplands show morainic material and glacial drift and the valleys carry sands, gravels and clays of outwash origin. Most of the glacial material is too sandy for brick manufacture but red and blue plastic clays do occur and could be utilized in the making of common brick and tile. Two brick yards were in operation at one time along the flats of Allegheny River west of Warren, using outwash clays of Wisconsin age and 5 to 10 feet in thickness. The Red Star Brick Company at Starbrick used the soft mud process of molding and burned common red brick. The Highhouse Brick Works was on the south side of the river 2 miles west of Warren. They used the dry-press process and made an excellent red brick. The use of glacial clay and terrace clay has declined in late years and manufacturers wishing to make brick in Warren County would probably use the Conewango shales. None of these are now in use within the county.

WAYNE COUNTY

Wayne County occupies the northeast corner of the State, bordering on New York State. It is a portion of the great Pocono plateau which is deeply dissected by the Delaware River on the northeast and in the southern part by Wallenpaupack Creek. The county is underlain chiefly by nearly horizontal Catskill strata, the only portion not Catskill being the small Moosic Mountain area on the mid-western border, made up of a ridge of Pocono, Mauch Chunk, and Pottsville strata, the northeast end of the Northern Anthracite Basin.

The brick-making materials of the county are limited to glacial clays, common over most of the plateau, and suitable for common brick manufacture; possibly the Mauch Chunk red shales west of Waymart where the Delaware & Hudson Railroad crosses them at the Susquehanna-Wayne county line; and to shales within the extensive area of the Catskill group.

Brick have been made from the Catskill shales at White Mills by C. Dorflinger & Sons, Inc., and at the State Hospital Brick Works at Waymart.

Only one sample in the county was tested, that being 334, a red and purplish Catskill shale along Highway 6, near the Fairview Hospital at Waymart. This showed good plasticity but low green strength, burned pink to brick red, and had a firing range from 1,100° to 1,150° C. It had poor burning qualities but could be used in making brick.

The only reference to the geology of the county necessary to set down is: White, I. C., *The Geology of Pike and Monroe counties: Penna. Second Geol. Survey, Rpt. G-6, 1882.*

Physical tests made on sample 334 are as follows:

Water of plasticity	22.1 percent
Linear drying shrinkage	4.2 percent
Time of slaking	9 minutes
Modulus of rupture	72 lbs. per sq. in.
Maximum linear burning shrinkage	9.4 percent at cone 1
Fusion point	Cone 12
Best burning range	Cone 02 to 1
Firing color	Pink to brick red
Suggested uses	A poor brick clay

WYOMING COUNTY

Wyoming County lies in the plateau country of northeastern Pennsylvania, south of Susquehanna County. It is underlain by nearly horizontal Pennsylvanian, Mississippian, and Upper Devonian strata. The whole of the county is glaciated.

The county is crossed from northwest to southeast by the North Branch of the Susquehanna River. Lehigh Valley Railroad and Highway 6 follow the river. Another branch of the same railroad crosses an area near Noxen, and the Delaware, Lackawanna and Western Railroad crosses the northeast corner of the county through Nicholson.

The Pennsylvanian (Pottsville) and Mississippian (Pocono) sandstones form a high, wild mountainous plateau in the southwestern townships, and carry no shales or clays of value. The Chemung division of the Devonian underlies the northwestern corner of the county from Mehoopany up the river through Meshoppen and Laceyville. In this area some greenish-gray shales are usually interbedded with thin sandstones to such an extent that they are of little value. Shaw in Bull. M 10 gives tests on a sample (62) of these shales collected on Lewis B. Carter's farm at Black Walnut. The shale was 30 feet thick and tan color. Its water of plasticity was 23.8 percent, drying shrinkage 9.62 percent by volume, time of slaking 5 minutes. It attained a maximum burning shrinkage of 22.15 percent by volume at cone 9. Shaw says this shale might be used in making building brick or tile.

West from Mehoopany to Loveton is a belt of lowlands underlain by Catskill red shales which near Loveton seem to be of good quality. East from Mehoopany a narrow belt of the Damascus shales of the Catskill formation passes through Lemon and Nicholson to the extreme northeast corner of the county. These Damascus beds are generally soft red shales. The rest of the county is underlain chiefly by Catskill beds of the more sandy types such as the Honesdale sandstone, the Cherry Ridge, and the Elk Mountain divisions. The Mount Pleasant shales of the Catskill lie southeast and southwest of Tunkhannock. They may yield good red shale.

The Catskill beds, however, from Mehoopany down the Susquehanna River to the southeastern corner of the county are prevailingly sandy and form high picturesque cliffs along the streams. There seems to be little available shale of good quality in the county.

Glacial clays and gravels line the Susquehanna River and many of the other valleys and boulder clays are available for small brick and tile operations at many points. Terrace clays are also available along the river south of Tunkhannock, some such clays being 200 feet above the present stream. None of these clays is now worked but

they are plastic and although not in large deposits they might be used in making common brick, drain tile, flower pots, or certain art pottery.

Selected references to the geology of Wyoming County:

White, I. C., Report on Wyoming, Lackawanna, Luzerne, Columbia, Montour and Northumberland Counties: Pennsylvania Second Geol. Survey, vol. G 7, 1883.

(The colored geologic map of Wyoming County was published in vol. G 6, 1882.)

Willard, B., The Devonian of Pennsylvania: Pennsylvania Topog. and Geol. Survey, Bull. G 19, 1939.

YORK COUNTY

York County lies along the Maryland border and is east of Adams County. Its eastern boundary is the Susquehanna River. It lies wholly within the low plains of the Piedmont Province. Lines drawn northeast-southwest across the county would divide it into three parts: a western third made up of Triassic sediments and Triassic igneous rocks; a central belt of Cambrian and Ordovician limestones and quartzites; an eastern third underlain by pre-Cambrian schists. In the extreme western corner of the county west of Dillsburg, a small part of the South Mountain projects into the county. In this mountainous area occur deposits of white and colored residual clays derived from the decay of the Antietam quartzite and Harpers phyllite of the Cambrian period. This siliceous sericitic white clay is suitable for filler in paper and paint. It is associated with limonite in the iron mines of Dogwood Hollow.

Two properties have been worked along Dogwood Run above Beavertown and two to four miles west of Dillsburg. The more important property is about on the York-Cumberland County line. This was formerly the Russell property, but now belongs to the Keystone-Empire Products Company, Inc. The clay was worked first about 1906 when the Vitrified Brick and Clay Company took out clay to make brick at their plant half a mile west of Dillsburg. This company went out of business before 1917. In 1918 a new plant was built to refine the clay, and was operated under the name of Mineral Products Company. The property changed hands several times and was last under the control of the Kaolin Corporation of America. They mined clay by a series of drifts and crosscuts and a 275-foot incline pitching 30 degrees into the mountain. It is reported that 75 feet of white clay was exposed. It was refined at their plant until 1930. The operation was idle from 1930 till

1937, during which time most of the buildings were torn down. In 1937 the clay deposit and site of the old plants were both purchased by the present company. It is expected that operations will be resumed about April 1941. Modern buildings with new equipment for clay refinement are nearly ready to operate (December 1940). Only new track to the clay property remains to be laid.

A second property is owned by Mr. Wes. Fishel of Dillsburg. This mine lies on the south side of Dogwood Run, 1½ miles above Beavertown. Two tunnels, now inaccessible, were driven, and Mr. Fishel states that he had a vertical face of white clay 30 feet high. The clay was formerly shipped to the Central Iron & Steel Company of Harrisburg, as a refractory cement and to the Penn Tile Works for floor tile manufacture. The clay was hauled by truck to Dillsburg. A small tonnage of clay was produced from this property during 1940. These white residual clays are similar to those to the west in Cumberland County, which are extensively mined.

The sericitic rhyolite schist in the western corner of York County and adjacent parts of Cumberland County has been prospected for white clay. The Sprenkle Clay Company of Latimore opened a mine in a greenish sericite schist and purplish clay derived from a purple schist in the lowland southeast of Long Mountain and five miles southwest of Dillsburg. A refinery was built and some white clay was produced. The product was not satisfactory, probably because of the presence of quartz grains in the schist, and the plant was abandoned.

The Manchester Shale Brick Company, one mile north of Emigsville, worked a 20-foot bank of the New Oxford shale and burned it in four down-draft and two up-draft kilns. The product was wire-cut shale brick, light or dark red. This plant was abandoned in 1930 and few of the buildings remain.

In the belt of Cambrian and Ordovician rocks that cross the center of the county, the decomposition of the schistose quartzites yields a residual clay which may be nearly pure white clay, a very sandy white clay, or a light-colored shaly clay. The decomposition of the limestones yields a plastic yellow and red clay which might be used in pottery or brick making. Decomposition of a sericitic schist in the Chickies quartzite half a mile south of Highmount yields a white, sandy clay. It was shipped from the Cooper quarry to the Foundry Supply Company at Stover Station, to be mixed with other materials for use as a molding sand under the name of "Korite." Some crude white clay was shipped in bulk.

One mile west of West York the plant of the old Gise Tile Works used a residual light gray to brown plastic clay derived from a sericite schist, probably the Chickies. Sample 330 represents an

8-foot bank of this, including some soil that was allowed to enter their mixture. This has good plasticity and high green strength. It fires to a salmon to good brick red, with a range from 1,000° to 1,200° C. It is suited to the manufacture of floor tile, art tile, pottery, flower pots, and brick. The plant produced hollow tile in 4 or 5 beehive kilns. These works were abandoned before 1928. All the buildings are gone.

In West York the Pfaltzgraff Pottery Company has a large plant and manufactures flower pots, artware and stoneware, fired in a straight and a circular continuous kiln. They use some residual clays derived from the decomposition of the Cambrian schists. Most of their clay comes from New Brighton, Pa. and from New Jersey.

The decomposition of impure schistose layers within the Conestoga limestone produces a plastic clay suitable for the manufacture of red brick and tile. Two brick companies are using the material near York.

The Wm. H. Grothe Brick Company has a brick plant southeast of York. Residual clay is stripped over a large area. The brick are burned in three Dutch kilns and the product is common brick.

The Spring Garden Brick and Clay Products Company operates a plant on the east edge of York and uses the residual clay in making red building brick, burned in a battery of 6 beehive kilns. Both common and face brick are made.

South of Hanover, brick was formerly made from residual clays derived from the Kinzer shales but this plant has been abandoned. Brick were made formerly also from ground Chickies slate, 1 mile southeast of Spring Plains, but the plant has been abandoned.

The eastern third of the county is underlain by schists of the Wissahickon and Peters Creek formations. These are mica, chlorite, and sericite schists, some of which should yield light-colored residual clays similar to those mentioned. No use is made of the residual clays from these schists.

Selected references to the geology of York County:

Stose, G. W. and Jonas, A. I., Geology and mineral resources of the Middletown Quadrangle, Pennsylvania: U. S. Geol. Survey, Bull. 840. 1933.

———, Geology and mineral resources of York County: Pennsylvania Topog. and Geol. Survey, Bull. C 67, 1939.

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